Staff Report of the

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

TOTAL MAXIMUM DAILY LOAD FOR SALINITY AND BORON IN THE LOWER SAN JOAQUIN RIVER

January 2002

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San Joaquin River TMDL Unit

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Acronyms/Abbreviations

AW	Applied Water
Basin Plan	Water Quality Control Plan for The Central Valley-Sacramento/San Joaquin Basins
BG	Background
CCR	California Code Regulations
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
CUA	Consumptive Use Allowance
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DMC	Delta-Mendota Canal
DPA	Drainage Project Area
DWR	California Department of Water Resources
EC	Electrical Conductivity
ETAW	Evapotranspiration of Applied Water
GBP	Grassland Bypass Project
GEA	Grasslands Ecological Area
GIS	Geographic Information System
GW	Groundwater
IRIS	Integrated Risk Information System
LA	Load Allocation
LC	Loading Capacity
LSJR	Lower San Joaquin River
M&I	Municipal and Industrial
MAF	Million Acre-Feet
MCL	Maximum Containment Level
MGD	Million Gallon Day
MOS	Margin of Safety
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point Source
Regional Board	Central Valley Regional Water Quality Control Board

RWQCB	Regional Water Quality Control Board
SAE	Seasonal Application Efficiency
SF	Scaling Factor
SJR	San Joaquin River
SJVDP	San Joaquin Valley Drainage Program
SNARL	Suggested No-Adverse-Response Level
SWRCB	State Water Resources Control Board
TAF	Thousand Acre-Feet
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TMML	Total Maximum Monthly Load
TV	Trigger Value
USBR	United States Bureau of Reclamation
U.S. EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Program
WDRs	Waste Discharge Requirements
WLAs	Waste Load Allocations
WY	Water Year
WQO	Water Quality Objective

EXECUTIVE SUMMARY

Water Body Name:	Lower San Joaquin River
Project Area:	Lower San Joaquin River Watershed downstream of the Mendota dam to Airport Way Bridge near Vernalis
Pollutants Addressed:	Salinity, boron
Extent of Impairment:	130 river miles, 2.9 million acres
Beneficial Uses Affected:	Agricultural supply, municipal supply
Watershed Characteristics:	Highly managed hydrology with numerous tributary impoundments and extensive diversion of river flows. Substantial water importation from Sacramento-San Joaquin Delta for irrigation and wetland supply. Flows and water quality are significantly influenced by surface and subsurface agricultural drainage. Water quality generally improves downstream as tributary inflows dilute agricultural and wetland discharges.

The Lower San Joaquin River (LSJR) is listed on the Federal Clean Water Act's 303(d) list as impaired for salinity and boron. The impairment extends from downstream of the Mendota Pool to the Airport Way Bridge near Vernalis. The 303(d) listing requires development of a Total Maximum Daily Load (TMDL) for salinity and boron in the LSJR. This TMDL has been developed to: 1) identify the major sources of salt and boron loading to the LSJR; 2) determine the maximum amount of salt and boron loading that occur while still meeting water quality objectives; and 3) equitably allocate the available assimilative capacity among the identified sources. The major components of the TMDL are a problem statement, numeric targets, a source analysis, and waste load allocations and load allocations.

The San Joaquin River is a major tributary of the Sacramento-San Joaquin Delta (Delta) that drains approximately 8.7-million acres in California's Central Valley. The LSJR watershed is located in portions of Stanislaus, Madera, Merced, San Joaquin, and Fresno Counties. The project area for the TMDL encompasses approximately 2.9 million acres and agriculture is the predominant land use (1.4-million acres). Salinity and boron water quality objectives in the LSJR are frequently exceeded during the irrigation season.

The existing water quality objectives for the LSJR at the Airport Way Bridge near Vernalis are used as the numeric targets for this TMDL. The salinity water quality objectives for the LSJR were adopted by the State Water Resources Control Board (SWRCB). Subsequent to the adoption of these water quality objectives, the SWRCB directed the Central Valley Regional Water Quality Control Board (Regional Board) to establish salinity objectives for the LSJR upstream of Vernalis. Consequently, the Regional Board is currently in the process of preparing an amendment to the *Water Quality Control Plan for the Central Valley* (basin plan) to establish salinity water quality objectives upstream of Vernalis. The Regional Board has adopted boron water quality objectives for the LSJR, however, these objectives were never approved by the U.S. Environmental Protection Agency (U.S. EPA). The existing boron objectives will therefore be reviewed as part of the ongoing Basin Plan Amendment process to establish new salinity objectives.

The source analysis describes the magnitude and location of the sources of salt and boron loading to the river. The watershed is divided into seven component sub-areas to elucidate differences in salt and boron loading between different geographic areas. Approximately 67 percent of the LSJR's total salt load and 85 percent of the boron load originates from the west side of the San Joaquin River (Grasslands and Northwest Side Sub-areas). Agricultural drainage, discharge from managed wetlands, and groundwater accretions are the principle sources of salt and boron loading to the river. Additionally, large-scale out-of-basin water transfers have reduced the assimilative capacity of the river, thereby exacerbating the salt and boron water quality problems. At the same time, imported irrigation water from the Delta has increased salt loading to the basin. Salts in supply water from the Delta account for almost half of the LSJR's mean annual salt load.

This TMDL uses a phased approach because it involves both point and non-point sources and the point source waste load allocation is based on a load allocation for which non-point source controls need to be implemented. A phased approach is also necessary because new or revised water quality objectives for salinity and boron may be established as part of the ongoing basin plan amendment. The waste load allocations and load allocations presented in this TMDL are designed to meet salinity and boron water quality objectives in the LSJR at the Airport Way Bridge near Vernalis. These waste load allocations and load allocations will need to be revised to reflect any new or revised water quality objectives. The methods used in this TMDL to develop allocations can be easily updated to calculate load allocations based upon new or revised water quality objectives.

Waste Load Allocations

Salt waste load allocations are proposed for the City of Turlock and the City of Modesto wastewater treatment plants, the two point sources that discharge directly to the LSJR. The waste load allocations are based on historical monthly salt loading from these two facilities. No waste load allocations are provided during months and year types for which there is no assimilative capacity in the LSJR at the Airport Way Bridge near Vernalis.

Load Allocations

The SJR salinity problem is not conducive to establishment of simple fixed or seasonal monthly load allocations for non-point sources. Consideration of the following factors necessitated use of a more complicated, formulaic TMDL:

- Salt and boron occur naturally in soils within the TMDL project area and these salts are readily evapoconcentrated through sequential re-use and consumptive use of water
- Significant salt loads are delivered to the basin from outside sources which restrict the ability of non-point source dischargers to comply with discharge load limits
- Strict adherence to fixed load allocations would restrict the ability to export salt from the LSJR basin such that there would be a net salt buildup in the watershed and long-term degradation of ground and surface waters

Base Load Allocation
Simple, fixed base load allocations for non-point source discharges from the seven geographic sub-areas have been established by calculating the available assimilative capacity of the LSJR at the Airport Way Bridge near Vernalis for the lowest anticipated flow conditions. The base load allocation calculation method uses an operations model to identify low flow conditions for a 73-year historical flow record, sorted by water-year type and month. Waste load allocations, background salt loading, and groundwater salt loading are subtracted from the total loading capacity to determine the salt load that can be allocated to non-point sources. The non-point source load allocation is apportioned into base load allocations for the seven geographic sub-areas. The base load allocation considers the seasonal variability of flows in the LSJR and includes an implicit margin of safety since the allocations are based upon the lowest flow conditions anticipated in the LSJR for each month and water year type.

Consumptive Use Allocation
Each sub-area is also provided a consumptive use allocation that allows for unlimited discharge of relatively high quality water. Through addition of this consumptive use allocation to all discharges, this TMDL recognizes the need to provide a base salt load allocation to account for evapoconcentration of salts in a high quality supply water and opportunity for discharging relatively high quality water.

Supply Water Relaxation and USBR Load Allocations
Additional load allocations have been provided to the Grasslands and Northwest Side Sub-areas to account for the local impact of degraded Central Valley Project (CVP) and surface water supplies delivered to these sub-areas. This additional salt load allocation is offset by establishing load allocations (limits) for the CVP. In effect, responsibility is placed on the U.S. Bureau of Reclamation (USBR) for salt loads in CVP water delivered to the TMDL project area that is in excess of a base load for an equivalent volume of Sierra Nevada quality water.

Real Time Relaxation
The base load allocations are very conservative because they have been designed to meet water quality objectives during critically low flow conditions. This TMDL recognizes that strict adherence to these base load allocations would restrict the ability to export salt from the LSJR basin, likely resulting in a net salt buildup in the watershed and long-term degradation of ground and surface waters. To overcome this restriction, the TMDL provides for an additional real-time load allocation. The real-time load allocation can be used in-lieu of the fixed base load allocation to maximize salt export from the LSJR basin while still meeting water quality objectives. To ensure that the water quality objectives

are met, development of an acceptable real-time management program is a prerequisite to use of real-time load allocations.

Linkage Analysis
A linkage analysis was developed as a check of the load allocations. The analysis shows that salinity water quality objectives will be exceeded approximately 15 percent of the time, even with the TMDL in effect. These water quality violations occur during months when no waste load allocations or load allocations are provided. This is a result of the high salt loading from groundwater accretions in association with extremely low river flows. No explicit load reductions are imposed for groundwater loading, although it is anticipated that compliance with this TMDL, which includes mitigation for salt imports by the USBR, and increased out of basin salt exports through real time load allocations, will result in no increase in groundwater salt accretions to the LSJR.

Boron allocations
No explicit boron waste load allocations or load allocations are needed to meet boron objectives for the LSJR near Vernalis. This TMDL shows that compliance with the established salt load allocations will result in attainment of boron objectives. The linkage analysis indicates that the boron water quality objectives for the LSJR at the Airport Way Bridge near Vernalis will be exceeded approximately one percent of the time with the TMDL in effect. These violations only occur during months and year-types for which no waste load allocations or load allocations are provided.

Load Allocation Summary
It is not possible to present simple, fixed load allocations for this TMDL. Following is a table containing descriptions and references for the various TMDL load allocations in this TMDL report.

Load Allocation Summary

Allocation Type	Description	Table	Page
Waste Load Allocations	Point source allocations	4-7	64
Base Load Allocation	Base load allocation for each geographic sub-area with no relaxations	4-15	70
Consumptive Use Allocation	A formulaic allowance that is based upon the volume of water being discharged	Equation 4-11	63
DMC Supply Water Relaxation	Additional load allocation provided to users that receive supply water from the Central Valley Project Delta Mendota Canal	4-19	76
SJR Supply Water Relaxation	Additional load allocation provided to users that divert supply water from the SJR	4-22	78
USBR Load Allocation	Load allocation provided to the USBR; the USBR is responsible for mitigation of salt loads delivered in excess of these allocations	4-23	79
Real Time Relaxation	An additional load allocation provided to allow for discharge of salt loads when assimilative capacity	Equation 4-19	81

1.0 PROBLEM STATEMENT

The LSJR is on California's Clean Water Act Section 303(d) list of impaired waters due to elevated concentrations of salinity and boron. Portions of the river are also listed as impaired due to elevated concentrations of selenium and organophosphorus pesticides. The SJR downstream of Vernalis is listed for depressed dissolved oxygen levels.

Since the 1940s, mean annual salt concentrations in the LSJR at the Airport Way Bridge near Vernalis have doubled and boron levels have increased significantly. Water quality monitoring data collected by the Regional Board and others (e.g. USGS, DWR, USBR etc.) indicates that water quality objectives for salinity and boron are frequently exceeded during certain times of the year and under certain flow regimes. Consequently, the river no longer supports all of its designated beneficial uses.

The salinity and boron water quality impairment in the river has occurred, in large part, as a result of large-scale water development coupled with extensive agricultural land use and associated agricultural discharges in the watershed. Upstream river flows have been severely diminished by the construction and operation of dams and diversions. Diverted natural river flows have been replaced with poorer quality (higher salinity) imported water that is primarily used for irrigating crops. Surface and subsurface agricultural discharges are the largest sources of salt and boron loading to the river. During the irrigation season, the river is heavily influenced by irrigation return flows. Water quality generally improves downstream as higher quality tributary flows dilute salt and boron concentrations.

The purpose of the Lower San Joaquin River TMDL for salinity and boron is: 1) to identify and quantify the sources of salt and boron loading to the river; 2) to determine the load reductions necessary to achieve attainment of applicable water quality objectives in order to protect the beneficial uses of water; and 3) to allocate salt and boron loads to the various sources and source areas within the watershed which, once implemented, will result in attainment of applicable water quality objectives.

1.1 Clean Water Act Section 303(d) and TMDL Process

Section 303(d)(1)(A) of the Clean Water Act requires that "Each State shall identify those waters within its boundaries for which the effluent limitations … are not stringent enough to implement any water quality standard applicable to such waters." The Clean Water Act also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and to establish TMDLs for those listed waters. Essentially, a TMDL is a planning and management tool intended to identify, quantify, and control the sources of pollution within a given watershed to the extent that water quality objectives are achieved and the beneficial uses of water are fully protected. A TMDL is defined as the sum of the individual waste load allocations (WLAs) from point sources, load allocations (LAs) from nonpoint sources and background loading, plus an appropriate margin of safety (MOS). Loading from all pollutant sources must not exceed the Loading Capacity

(LC) of a water body, the LC is the amount of pollutant that a water body can receive without violating Water Quality Objectives.

$$TMDL = LC = \sum WLA + \sum LA + MOS \qquad (1\text{-}1)$$

The specific requirements of a TMDL are described in 40 CFR 130.2 and 130.7, and Section 303(d) of the Clean Water Act, as well as in U.S. Environmental Protection Agency guidance (U.S. EPA 1991). In California, the authority and responsibility to develop TMDLs rests with the Regional Boards. The Environmental Protection Agency (U.S. EPA) has federal oversight authority for the 303(d) program and may approve or disapprove TMDLs developed by the state. If the EPA disapproves a TMDL developed by the state, the EPA is then required to establish a TMDL for the subject water body.

1.2 Watershed Setting and Project Scope

The southern part of the Central Valley of California is comprised of two hydrologic basins: the San Joaquin River and the Tulare Lake Basins. The San Joaquin River Basin is drained by the San Joaquin River, which discharges to the Sacramento-San Joaquin Delta. The Tulare Lake Basin is for the most part an internal drainage basin that occasionally overflows into the San Joaquin river basin during extremely high flood flow periods. Otherwise these watersheds have separate drainages.

The San Joaquin River (SJR) watershed is bounded by the Sierra Nevada Mountains on the east, the Coast Ranges on the west, the Delta to the north, and the Tulare Lake Basin to the south. From its source in the Sierra Nevada Mountains, the San Joaquin River flows southwesterly until it reaches Friant Dam. Below Friant Dam, the SJR flows westerly to the center of the San Joaquin Valley near Mendota, where it turns northwesterly to eventually join the Sacramento River in the Delta. The main stem of the entire SJR is about 300 miles long and drains approximately 13,500 square miles.

The major tributaries to the San Joaquin River upstream of the Airport Way Bridge near Vernalis (the boundary of the Sacramento-San Joaquin Delta) are on the east side of the San Joaquin Valley, with drainage basins in the Sierra Nevada Mountains. These major east side tributaries are the Stanislaus, Tuolumne, and Merced Rivers. The Consumnes, Mokelumne, and Calaveras Rivers flow into the San Joaquin River downstream of the Airport Way Bridge near Vernalis. Several smaller, ephemeral streams flow into the SJR from the west side of the valley. These streams include Hospital, Ingram, Del Puerto, Orestimba, Panoche, and Los Banos Creeks. All have drainage basins in the Coast Range, flow intermittently, and contribute sparsely to water supplies. Mud Slough (north) and Salt Slough also drain the Grassland Watershed on the west side of San Joaquin Valley. During the irrigation season, surface and subsurface agricultural return flows contribute greatly to these creeks and sloughs.

The geographic scope of this TMDL is the LSJR downstream of the Mendota Dam to the Airport Way Bridge near Vernalis. The LSJR watershed is defined as the area draining to the San Joaquin River downstream of the Mendota Dam and upstream of Vernalis. For TMDL planning and analysis purposes, the LSJR watershed excludes areas upstream of dams on the major Eastside reservoirs: New Don Pedro, New Melones, Lake McClure, and similar Eastside reservoirs in the LSJR system. The southeastern boundary of the TMDL project area is formed by the LSJR (from the Friant Dam to the Mendota pool) to include the lands that drain to the Mendota Pool. The LSJR Watershed, as defined here, drains approximately 2.9 million acres (Figure 1-1 and Figure 1-2). The geographic attributes of the TMDL project area are discussed in detail in Section 3.4 of this report.

Figure 1-1: Location Map

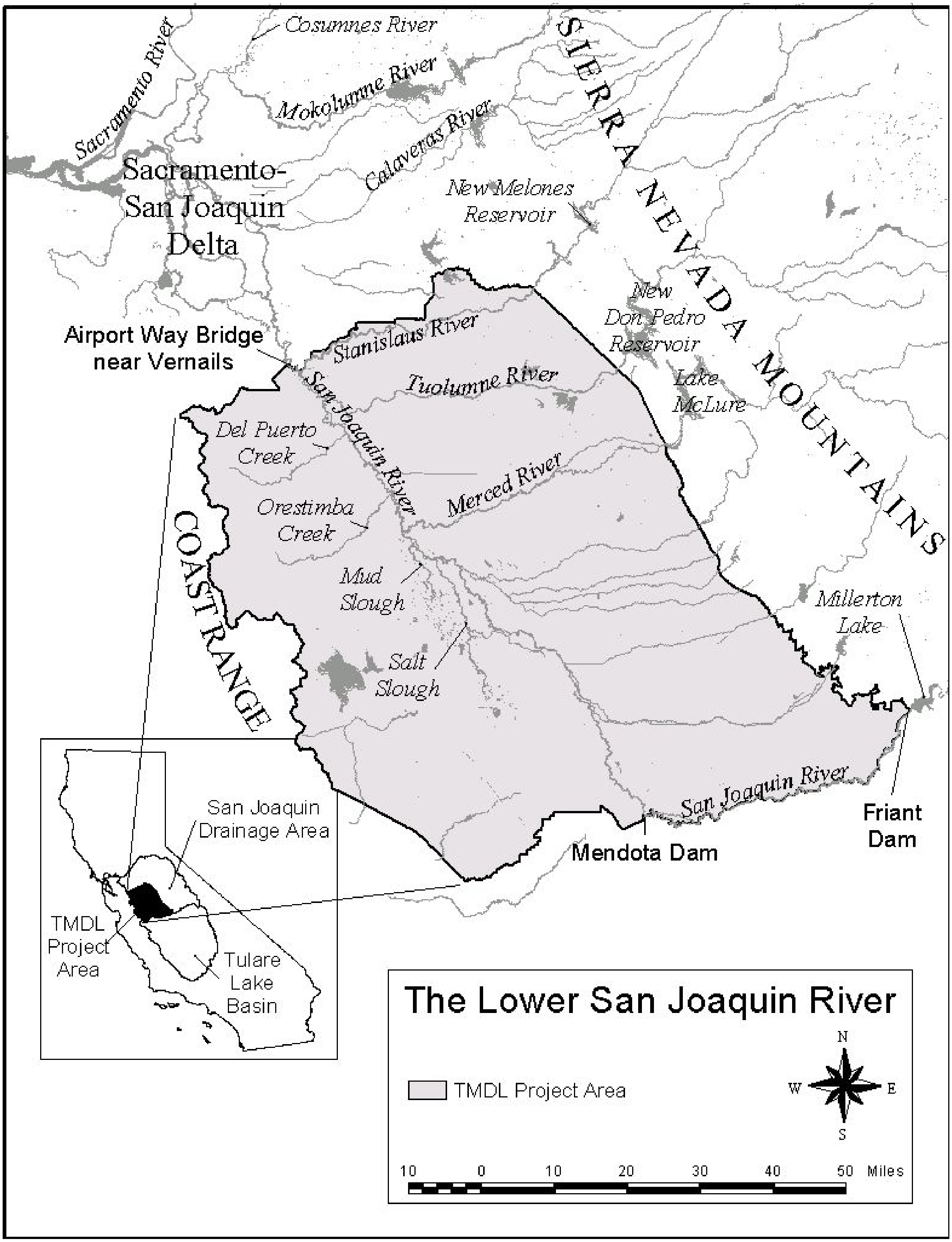
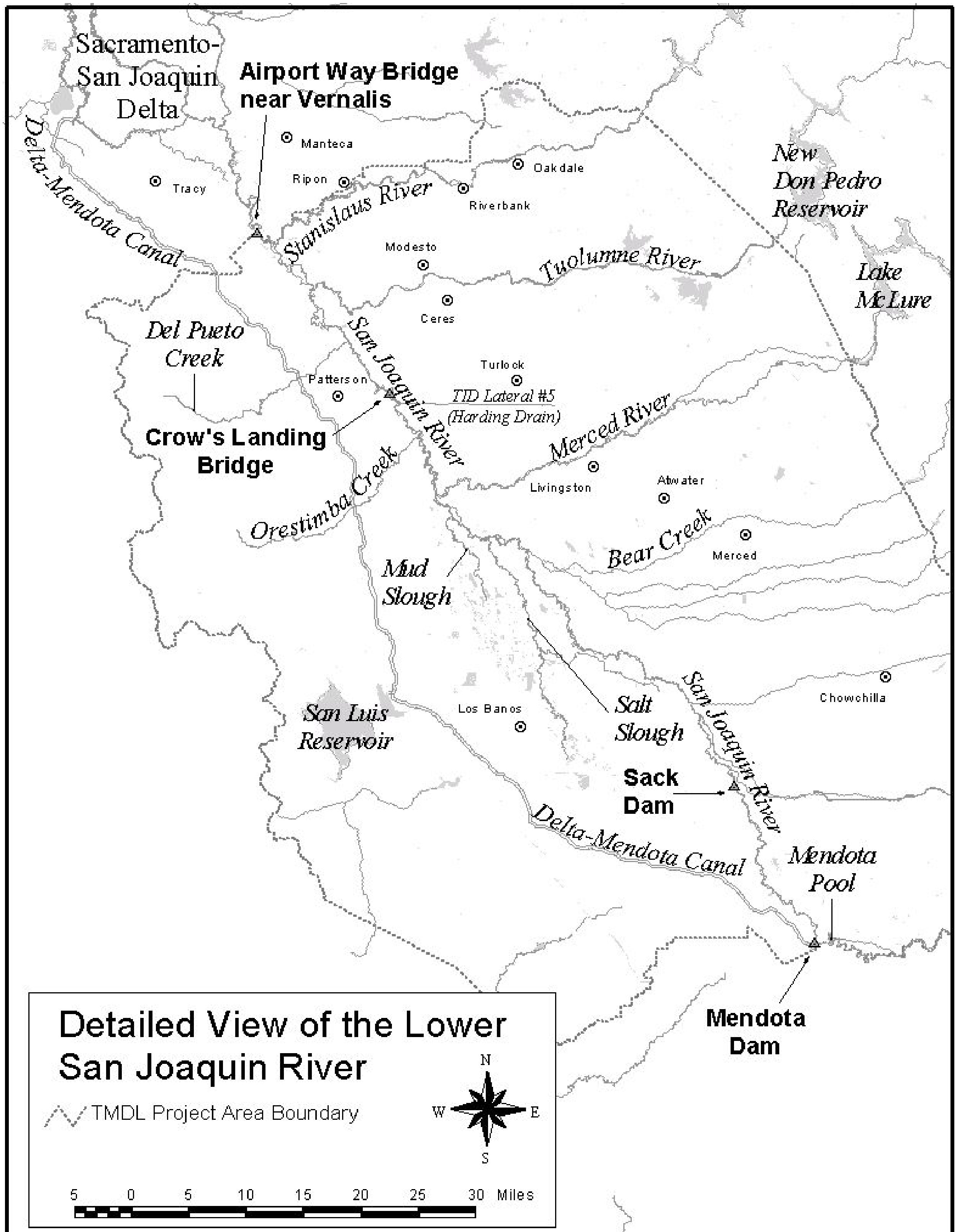


Figure 1-2: Detail View of TMDL Project Area



1.3 Background

The San Joaquin Valley occupies approximately 18 million acres in the southern portion of California's Central Valley, accounting for almost 18 percent of the total land area of the state. The San Joaquin Valley has historically been recognized as a leading region for agricultural production in the State of California as well as the nation. The valley is home to five of the top ten agricultural producing counties in the U.S. with approximately five million acres of land devoted to irrigated agriculture (Parsons, 1986). Accordingly, the region's economy and historical urban development have been closely linked to agricultural activities. Agricultural prosperity in the San Joaquin Valley has not come without its problems. Over 100 years of water development and irrigation has resulted in significant degradation of surface and groundwater quality. Irrigation of soils containing naturally high levels of salts and certain trace elements, coupled with extreme hydrologic modifications and water importations has accelerated the accumulation of salts and boron in the soil, groundwater, and surface waters of the region. Salt and boron concentrations have been elevated to the extent that agricultural productivity has been diminished in some areas and receiving waters no longer meet water quality objectives during certain times of the year.

In addition to agriculture, the San Joaquin Valley is known for its high natural resource values. It is estimated that the San Joaquin Valley once contained about 1.1 million acres of permanent and seasonal wetlands, with approximately 731,000 acres occurring within the San Joaquin River Basin and 360,000 acres occurring within the Tulare Lake Basin. Prior to major water developments, the San Joaquin River watershed supported a superlative Chinook Salmon fishery and tens of thousands of salmon probably spawned in its headwaters (SWRCB, 1987), however, steady declines in fish and wildlife habitat have occurred in connection with large-scale agricultural and urban water development. Approximately 85 percent of the historic seasonal and permanent wetlands in the San Joaquin Valley have been drained and/or reclaimed for agricultural purposes (SJVDP, 1990a). The San Joaquin Valley, however, remains a critical habitat for fish and wildlife; as many as twenty-four state or federally listed threatened and endangered species (plant and animal) are now found in the valley.

The San Joaquin River is also an important drinking water source for the State of California. San Joaquin River flows account for approximately 15 percent of the total flows in the Delta. The Delta provides drinking water for over two thirds of the people in California (more than 20 million people) (SWRCB, 1995; CALFED, 1999). Most of Southern California, a major portion of the San Francisco Bay area, and many Central Valley communities rely on the Delta and it's tributaries for their drinking water. The major Sierra Nevada tributaries of the San Joaquin River provide drinking water to residents of the San Francisco Bay area and communities in the San Joaquin Valley. The main stem of the San Joaquin River is not currently a direct source of drinking water for any large communities, although potential domestic supply is a designated beneficial use. Elevated levels of salt, boron, and other constituents have diminished the suitability of the main stem of the San Joaquin River as a municipal water supply and have raised concerns regarding water treatment and reliability in the Delta itself.

The Lower San Joaquin River is listed in accordance with Section 303(d) of the Clean Water Act for exceeding salinity and boron water quality objectives. The 130-mile reach of the LSJR from Mendota Pool to Vernalis has been listed as impaired. This reach drains an area of approximately 2.9-million acres. Portions of the watershed are also 303(d) listed for organophosphorus pesticides, diazinon and chlorpyrifos, and selenium. The Delta is also listed for dissolved oxygen. This technical TMDL focuses exclusively on the salinity and boron impairment. Technical TMDLs for the remaining pollutants are being developed separately to better address the specific needs of those pollutants.

Water quality data collected by Regional Board staff over the past 15 years indicates that water quality objectives have been routinely exceeded throughout the lower river. Figure 1-3 shows the 30-day running average EC at Vernalis for Water Years 1986 through 1998. Superimposed on this figure are the seasonal water quality objectives. The non-irrigation season salinity objective (applies 1 Sep.- 31 Mar.), was exceeded 11 percent of the time and the irrigation season salinity objective (applies 1 Apr.- 31 Aug.), was exceeded 49 percent of the time. This rate of exceedance occurred even though releases were made from New Melones Reservoir on the Stanislaus River during much of this period, specifically to help meet water quality objectives at Vernalis. If the Vernalis objectives were applied upstream at Crows Landing, the non-irrigation season objective would have been exceeded 67 percent of the time and the irrigation season objective would have been exceeded 78 percent of the time. This higher rate of exceedance at Crows Landing is due to reduced dilution flows, as Crows Landing is upstream of both the Stanislaus and the Tuolumne River inflows.

Surface and subsurface agricultural drainage represent the largest sources of salt and boron loading to the LSJR. The vast majority of this agriculturally derived salt and boron loading to the river originates from lands on the west side of the LSJR watershed. Soils on the west side of the San Joaquin Valley are derived from rocks of marine origin in the Coast Range that are high in salts and boron. Dry conditions make irrigation necessary for nearly all crops grown commercially in the watershed. Salt and boron are leached from these west side soils when irrigation water is applied. The mobilized salts move into the shallow groundwater and subsurface drainage is produced when farmers drain the shallow groundwater from the root zone to protect their crops. The discharge of subsurface drainage has resulted in elevated salt and boron concentrations in the LSJR and certain tributaries. Large quantities of water are imported from the Delta to irrigate much of the west side of the basin. The imported water supplies are relatively high in salts and the water imported to the basin represents a significant portion of the SJR's total salt load. Groundwater accretions to the river are another significant source of salt and boron loading to the LSJR, as ongoing irrigation practices have led to accumulation of salts in the unconfined and semi-confined aquifer that underlies most of the west side of the San Joaquin Valley and lands on the east side of the San Joaquin Valley directly adjacent to the river.

Discharges from managed wetlands also contribute to the LSJR's salt and boron load. The LSJR watershed contains over 160,000 acres of wetland habitat, most of which are located in the Grassland Watershed. These wetlands are either managed by the California

Department of Fish and Game (DFG), United States Fish and Wildlife Service (USFWS) or by water districts on behalf of privately owned duck and gun clubs. Water is applied to maintain the wetlands, and saline discharges occur when flooded wetlands are drained. Other less significant sources of salt and boron loading include municipal and industrial discharges as well as loading from the higher quality east side tributaries. The sources of salt and boron loading and their relative contribution to cumulative water quality degradation are discussed in more detail in the source analysis section.

TMDL development for salt and boron in the LSJR presents unique challenges because of the nature of the pollutants being addressed and because of the way water is managed in the basin. Land management and water delivery practices have exacerbated salt and boron loading to the LSJR. Salt and boron, however, are not conventional pollutants in that they are naturally occurring in the water and soils of the region and their concentrations increase, through evapoconcentration, with each sequential re-use of water in the basin. Additionally, the LSJR flows to the Delta and salts are re-circulated to the basin when Delta water is pumped and delivered back to lands that drain to the LSJR. Supply water from the Delta is relatively high in salts. The salts imported to the LSJR basin from the Delta need to be exported; simply limiting saline discharges through static load allocations/reductions could result in a net build-up of salt in the watershed and further deterioration of surface and groundwater quality. Therefore, this TMDL must recognize the unique nature of the LSJR watershed, the need to account for salt inputs to the basin as well as outputs, and the need to export salts by utilizing the assimilative capacity of the river.

Historical Agricultural Drainage Issues

Agricultural drainage problems are not new to the San Joaquin Valley. Concerns regarding inadequate drainage and salt accumulations arose around the turn of the century and date as far back as the 1880s and 1890s (SJVDP, 1990b). Early irrigation practices involved the intentional over-irrigation of fields to raise the local water table so that subsurface water would be available to crops during a portion of the dry summer season, however, water was applied in excess of plant uptake and consequently some areas became waterlogged. Additionally, evapotranspiration of applied water resulted in salt build up in the soil and shallow groundwater. By the late 1800s, salt accumulations and poor drainage had already adversely impacted agricultural productivity and some areas had to be removed from production (SWRCB, 1987).

Advancements in pumping technology during the 1920's and 1930's led to increased groundwater pumping and accelerated agricultural production in the region. Groundwater withdrawals were mining the groundwater basin (overdrafting) resulting in lowering the water table, which temporarily alleviated the waterlogging problem and allowed for salts to be leached below the crop root zone. In 1951, because of the continued groundwater overdraft, the Delta Mendota Canal (DMC) of the Federal Central Valley Project (CVP) began delivering surface water from northern California and the Sacramento-San Joaquin Delta to the northern San Joaquin River Basin. Water delivered by the CVP essentially replaced and supplemented natural river flows that were diverted out of the San Joaquin Basin at Friant Dam (Millerton Lake) and reduced the groundwater overdraft. Large-scale surface and ground water development projects resulted in the rapid expansion of irrigated agriculture on the west side of the San Joaquin River; irrigated agriculture increased from 293,000 acres in 1950 to 402,000 acres by 1957 (SWRCB, 1987).

Land Use

Agriculture is the primary land use in the LSJR watershed with lesser acreages of wetland and urban areas. According to the latest (1996) complete crop survey information from the Department of Water Resources, there are approximately 1.4 million acres of agricultural land use in the LSJR watershed. The LSJR watershed also contains approximately 160,000 acres of wetlands within the Grassland Ecological Area (GEA). Additional acreage is in either urban, fallow farmland, or in upland wildlife areas that are not wetlands. Urban areas within the LSJR watershed are expanding and the population of the 13 largest cities in the LSJR watershed increased an average of 1.5 percent between 1998 and 1999 (CDF, 1999). Modesto is the largest city in the LSJR watershed, with a current population about 184,600. Other larger urban areas in the LSJR watershed include the cities of Merced (pop. 62,800), Turlock (pop. 51,900), Ceres (pop. 32,400), Atwater (pop. 22,250), and Los Banos (pop. 22,200).

The LSJR Basin consists of areas with markedly different supply water quality, land use patterns, and other factors that may affect water quality. For the purpose of describing these differences, the LSJR basin has been divided into seven sub-areas. These sub-areas vary greatly with respect to their land use patterns and relative contribution of salt and boron loads to the LSJR, as discussed in detail in the source analysis.

Hydrology

Precipitation is unevenly distributed throughout the SJR Watershed. About 90 percent of the precipitation falls during the months of November through April. Normal annual precipitation ranges from an average of eight inches on the valley floor (in the trough of the basin) to about seventy inches at the headwaters in the Sierra Nevada. Precipitation at the higher elevations primarily occurs as snow. Potential evaporation on the valley floor is over 50 inches annually.

The hydrology of the San Joaquin River is complex and highly managed through the operation of dams, diversions, and supply conveyances. Water development has fragmented the watershed and greatly altered the natural hydrograph of the river. Runoff from the Sierra Nevada and foothills is regulated and stored in a series of reservoirs on the east side of the SJR. There are 57 major reservoirs in the basin that have the capacity to store over 1,000 acre-feet of water; four of these can store over 1,000,000 acre-feet each. Friant Dam (Millerton Lake) on the main stem of the upper SJR, which was built in 1942, has a capacity of just over 500,000 acre-feet. Operation of these reservoirs greatly influence the water quality of the LSJR.

Most of the natural flows from the Upper SJR and it’s headwaters are diverted at the Friant Dam via the Friant-Kern Canal to irrigate crops outside the SJR Basin. This leaves much of the river dry between Friant Dam and the Mendota Pool, except during periods of wet weather flow and major snow melt. Water is imported to the basin from the southern Delta via the DMC to replace the flows that are diverted out of the basin to the south. Some water in the DMC is delivered directly to the west side of the SJR for agricultural supply, but the majority of DMC water is delivered to the Mendota Pool. Storage in the Mendota Pool is augmented by groundwater pumping from the adjacent aquifer and from incidental upstream releases from Millerton Lake. Water is discharged from the Mendota Pool to irrigation canals that supply farmlands on the west side of the basin. Water is also directly released to the LSJR, and various agricultural users divert water from the SJR between the Mendota Pool and the Sack Dam. Most or all of the remaining flow in the river is diverted at Sack Dam. As a result, the SJR downstream of Sack Dam and upstream of Bear Creek frequently has little or no flow except during flood flows. During non flood-flow periods, this reach of the SJR flows intermittently and is composed of groundwater accretions and agricultural return flows. The SJR downstream of Bear Creek once again becomes a permanent stream that flows all year. The flow in the reach of the SJR downstream of Bear Creek and upstream of the Merced River confluence, however, is dominated by agricultural and wetland return flows and by groundwater accretions. Downstream, the Merced, Tuolumne, and Stanislaus Rivers add substantial flow in the LSJR.

The mean annual discharge for the SJR Basin, as measured at a gaging station near Vernalis, was a little over three million acre-feet per year between 1930 and 1998, but there were large seasonal and annual variations (Figure 1-4). The lowest annual discharge, of approximately 400,000 acre-feet, occurred in Water Year 1977. The highest annual discharge, of over 15 million acre-feet occurred in Water Year 1983. Superimposed on the annual data in Figure 1-4 is the fifteen-year moving average discharge. The fifteen-year moving average helps identify the long-term trends that may be obscured by the annual variability of discharge. There was a significant decrease in the moving average in the 1950s, particularly during the summer irrigation season. This drop in annual and irrigation season discharge occurred following completion of Friant Dam in 1948 when SJR water was diverted for use outside of the SJR Basin. The moving average of the mean annual discharge increased again in the 1970s and early 1980s so that the fifteen-year moving average was approximately 800,000 acre-feet per year lower in the late 1990s than in the late 1940s. Almost all of this reduction in Basin discharge occurs during the April through August irrigation season.

The actual annual discharge shown in Figure 1-4 is considerably lower than the unimpaired runoff in the Basin. Unimpaired runoff is the runoff that would occur if there were no reservoirs or consumptive use of water. Between 1979 and 1992 the mean annual unimpaired runoff in the basin was 2.4 million acre-feet higher than the actual mean annual discharge of 3.7 million acre-feet (United States Geological Survey, 1997). The difference is due to consumptive use, attributable mostly to losses from agriculture (Califronia Department of Water Resources, 1994).

Hydrogeology

A 20 to 120 foot clay layer, known as the Corcoran Clay, underlies most of the San Joaquin Valley. The Corcoran Clay ranges in depth from about 200 to 800 feet below the ground surface (Kratzer, 1985). The relatively impervious Corcoran Clay layer creates a boundary between a confined aquifer lying below the clay, and a semi-confined aquifer above the clay. The semi-confined aquifer is comprised of three basic hydrogeologic units that include the Coast Range alluvium, Sierra Nevada sediments, and flood basin deposits. These three fundamental hydrogeologic units each have a different texture, hydrologic property and chemical characteristic. The Coast Range alluvium, which is primarily located on the west side of the LSJR, was derived from the marine rock parent material the makes up the Coast Range. These marine sediments contain naturally high levels of salts, boron and other trace elements. Soils on the east side of the valley trough were predominately derived from the igneous parent material of the Sierra Nevada and, consequently, contain relatively low levels of salts and trace elements. The floodplain deposits consist of a relatively thin and more recent deposit that is mainly located in the valley trough.

The California Department of Water Resources (DWR) collected water quality data from wells in the LSJR Basin until 1990 (DWR, 1999). Observation, domestic, and agricultural supply wells of varying depth were sampled. The United States Geological Survey (USGS) conducted a comprehensive groundwater quality study that spanned the west side of the San Joaquin Valley in 1984 (Deverel, *et al.,* 1984). Observation wells ranging from 10 to 30 feet below ground surface were sampled. Between these two data sets, a total of 74 shallow wells were sampled between 1980 and 1990; thirty-seven each by the USGS and DWR. The wells were located either adjacent to the LSJR, or in the vicinity of drainages that terminate at the SJR. A number of wells were near Mud Slough (north) and Salt Slough.

Groundwater quality on the west side of the LSJR was found to be of significantly poorer quality than groundwater on the east side of the river. On the west side of the LSJR the average electrical conductivity (EC) was approximately 5,800 μS/cm, and ranged from 570 to 59,000 μS/cm; the median EC was 1,900 μS/cm. The average boron concentration was 7.7 mg/L and ranged from 0.2 to 120 mg/L; the median boron concentration was 1.2 mg/L. Wells on the east side of the SJR had an average EC of approximately 900 μS/cm and ranged from 290 to 3,200 μS/cm; the median EC was 630 μS/cm. The average boron concentration was 0.3 mg/L, with a range of 0.1 to 0.8 mg/L; the median boron concentration was 0.2 mg/L. Groundwater salinity is highest in the south. Salinity ranged from 800 to 2,300 μS/cm in wells less than five miles from the SJR, in the reach from Mendota Dam to the confluence of the Tuolumne River. North of the Tuolumne River, salinity ranged from 310 to 780 μS/cm in wells within five miles of the SJR.

1.4 Available Data

Since May of 1985 the Regional Board has conducted water quality monitoring in the San Joaquin River basin to evaluate the impact of agricultural drainage on the San Joaquin River and to assess the water quality of the river with respect to compliance with water quality objectives. The Regional Board's monitoring program in the LSJR watershed has primarily focused on salinity, boron, and selenium. There have been up to 37 stations monitored in the LSJR watershed at various frequencies since 1985. This monitoring data is available in a series of annual staff reports published by the Regional Board (Chilcott, 2000). In addition to these annual staff reports, extensive water quality data is also available in the following Regional Board staff reports:

Agricultural Drainage Contribution To Water Quality In The Grassland Watershed of Western Merced County, California: October 1995-September 1997

Loads of Salt, Boron, and Selenium in the Grassland Watershed and Lower San Joaquin River October 1985 to September 1995: Volumes I and II

Compilation of Electrical Conductivity, Boron, and Selenium Water Quality Data for the Grassland Watershed and Lower San Joaquin River May 1985 - September 1995

Additionally, the USGS and DWR have collected extensive flow and water quality data from the TMDL project area. The USGS and DWR data used in the report is discussed in the Source analysis.

Figure 1-3: Electrical Conductivity for Lower San Joaquin River at Vernalis, 1985-1998

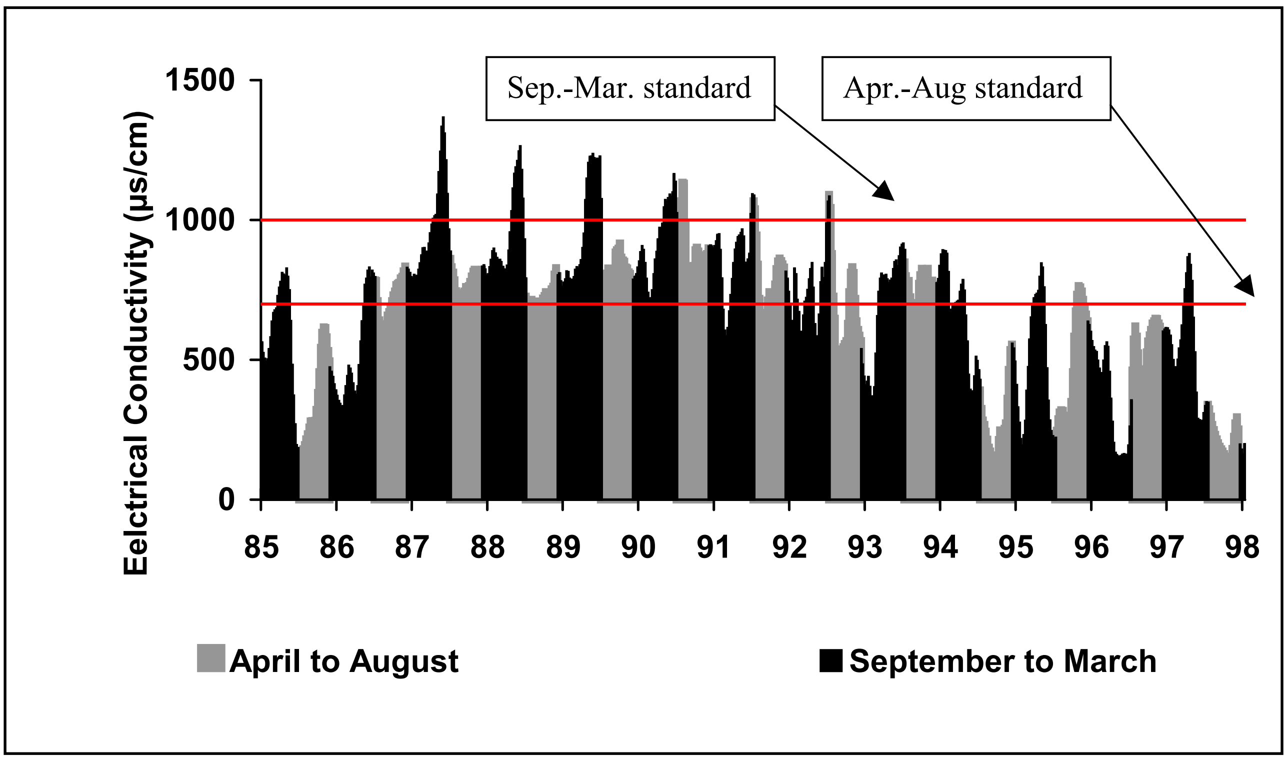
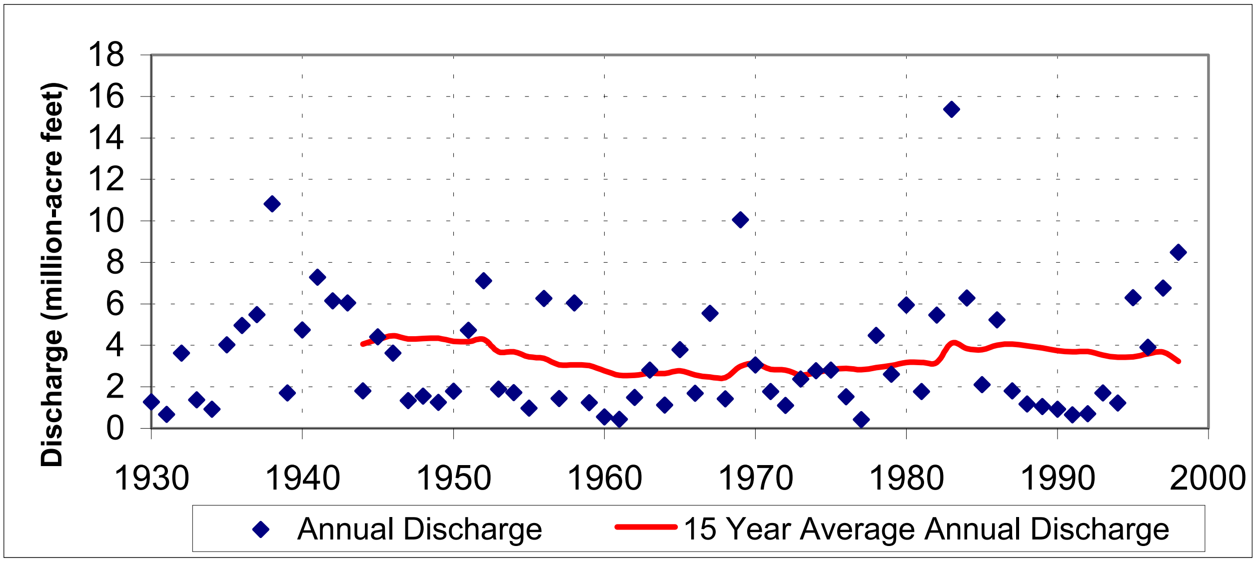


Figure 1-4: Annual Average Discharge for Lower San Joaquin River at Vernalis, 1930-1998



2.0 TARGET ANALYSIS

This target analysis contains recommendations and supporting information for developing numeric targets for a TMDL for salinity and boron in the LSJR. Once established, these targets will identify the specific instream goals or endpoints for the TMDL, which equate to the attainment of water quality standards. The water quality objectives for EC (salinity) and boron in the LSJR at Vernalis are contained in the Basin Plan. The existing water quality objectives for salinity and boron in the LSJR are used as Numeric Targets for this TMDL. The San Joaquin River at Vernalis is the most upstream location where salinity water quality objectives have been established. Therefore, the San Joaquin River at Vernalis has been selected as the compliance point for this TMDL.

The Regional Board is currently in the process of reviewing the salinity and boron control program in the Basin Plan. Any proposed Basin Plan Amendment may set new water quality objectives for salt and boron in the LSJR upstream of the Airport Way Bridge near Vernalis. Accordingly, this TMDL will be updated to reflect any revisions to the water quality objectives for salinity and boron.

2.1 Applicable Standards, TMDLs, and Numeric Targets

Section 303 of the Federal Clean Water Act requires states to develop and adopt Water Quality Standards, which consist of designated beneficial uses of water and water quality criteria. In California, the State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCBs) prepare and adopt *Water Quality Control Plans* (Basin Plans) for waters within their respective jurisdictions. The Basin Plans contain the designated beneficial uses for specific waterbodies and water quality objectives needed to protect those uses. Collectively, the state water quality objectives and beneficial uses contained in the Basin Plans fulfill the states obligation to establish Water Quality Standards.

State water quality objectives and other components of the Basin Plan must comply with antidegradation policies adopted by the State Water Board and U.S. EPA. The states' anti-degradation policy requires the maintenance of existing high quality water, except under certain circumstances that are spelled out in the policy. This means that the concentrations of contaminants should not be increased above natural background levels, unless a change in water quality will be consistent with maximum benefit to the people of the state and will not adversely affect beneficial uses.

Section 303(d) of the Clean Water Act also requires states to establish a priority ranking of impaired waters that are not meeting water quality objectives and to develop TMDLs for those listed waters. Essentially, a TMDL is a planning and management tool intended to identify, quantify, and control the sources of pollution within a given watershed to the extent that water quality objectives are achieved and the beneficial uses of water are fully protected. A TMDL is defined as the sum of the individual waste load allocations (WLAs) from point sources, load allocations (LAs) from nonpoint sources and background loading, plus an appropriate margin of safety (MOS). Loading from all pollutant sources must not exceed a water body's Loading Capacity (LC), the amount of pollutant loading that a water body can receive without violating water quality objectives.

To develop a TMDL, it is necessary to establish quantifiable indicators or end points that can be used to evaluate instream water quality with respect to attainment of applicable water quality objectives and the protection of designated beneficial uses. Once an indicator has been selected, a target value or threshold value for that indicator must be established that seeks to distinguish between the impaired and unimpaired state of the waterbody (U.S. EPA, 1999). In this case, salinity and boron will be used directly as numeric targets because of their relative ease of measurement and the abundance of existing data for these constituents. Additionally, numeric water quality objectives have already been established for salinity (EC) and boron in the LSJR. These numeric objectives provide quantifiable and finite target values that can be used to calculate the river's loading capacity.

As mentioned above, Regional Board staff is currently in the process of preparing a Basin Plan Amendment intended to address salinity and boron impairment in the LSJR upstream of the Airport Way Bridge Near Vernalis. Staff anticipates that the Basin Plan Amendment, once adopted, will contain revised water quality objectives for salinity and boron. These revised objectives will be established to protect the most sensitive beneficial uses of water in the LSJR, including agricultural and municipal supply.

Regional Board staff is reevaluating the existing objectives for boron and salinity in the LSJR for the following reasons:

- U.S. EPA did not approve the boron objectives for the LSJR adopted by the Board in 1988. U.S. EPA has not promulgated new objectives, and therefore the Board must do so.

- The State Water Resources Control Board (State Water Board) has directed the Regional Board to set numerical objectives for salinity in the San Joaquin River upstream of Vernalis.

- Water Code Section 12232 requires that state agencies do nothing to cause further significant degradation of the quality of water in the San Joaquin River between its confluence with the Merced River and the junction with Middle River in the southern Delta.

Existing State Water Quality Objectives and Beneficial Uses

The beneficial uses of waters in the LSJR Watershed, as identified in the *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Basin Plan) are listed in Table 2-1. The existing salinity water quality objectives for the San Joaquin River at Vernalis were originally established by the SWRCB pursuant to the *Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (SWRCB, 1995) and are presented in Table 2-2. The existing salinity water quality objectives for the San Joaquin River at Vernalis are 1000 μS/cm between September 1 and March 31, and 700 μS/cm between April 1 and August 31.

Water quality objectives for boron were adopted by the Regional Board and approved by the State Board in 1988 and are also presented in Table 2-2. Monthly mean and maximum boron water quality objectives on the San Joaquin River from Sack Dam to the mouth of the Merced River are 2.0 mg/L and 5.8 mg/L, respectively (15 March-15 September). Monthly mean water quality objectives for boron from the mouth of the Merced River to Vernalis are 0.8 mg/L (15 March-15 September) and 1.0 mg/L (16 September-14 March). Maximum boron water quality objectives for this reach of the river are 2.0 mg/L (15 March-15 September) and 2.6 mg/L (16 September-14 March). During critical water years the monthly mean objective for boron is relaxed from 1.0 mg/L to 1.3 mg/L between 16 September and 14 March.

Table 2-1: Lower San Joaquin River Beneficial Uses

LOWER SAN JOAQUIN RIVER REACH	MUN	AGR		PROC	REC-1		REC-2	WARM	COLD	MIGR		SPWN		WILD
	MUNICIPAL AND DOMESTIC SUPPLY	IRRIGATION	STOCK WATERING	INDUSTRIAL PROCESS	CONTACT	CANOEING AND RAFTING	OTHER NONCONTACT	FRESHWATER HABITAT-WARM	FRESHWATER HABITAT-COLD	WARM	COLD	WARM	COLD	WILDLIFE HABITAT
MENDOTA DAM TO SACK DAM	P	E	E	E	E	E	E	E		E	E	E	P	E
SACK DAM TO MERCED RIVER	P	E	E	E	E	E	E	E		E	E	E	P	E
MERCED RIVER TO VERNALIS	P	E	E	E	E	E	E	E		E	E	E		E

E=EXISTING P=POTENTIAL

Table 2-2: Applicable Water Quality Objectives

SALINITY		
Reach	Irrigation Season (Apr1-Aug31)	Non-Irrigation Season (Sep1 –Mar 31)
Vernalis Only	700 µS/cm (30-day running avg.)	1000 µS/cm (30-day running avg.)
BORON		
Reach	Irrigation Season (Mar 15-Sep15)	Non-Irrigation Season (Sep16-Mar14)
Sack Dam to Merced River	2.0 mg/L (max.) 0.8 mg/L (monthly mean)	5.8 mg/L (max.) 2.0 mg/L (monthly mean)
Merced River to Vernalis	2.0 mg/L (max.) 0.8 mg/L (monthly mean)	2.6 mg/L (max.) 1.0 mg/L (monthly mean) 1.3 mg/L (monthly mean)*

* Critical year relaxation value

2.2 Pollutant Properties: Salinity

Salinity is the total dissolved mineral concentration in water. In natural waterbodies, salts typically consist of anions such as carbonates, chlorides, and sulfates, and cations such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). Table 2-3 lists the major cations and anions that make up the salinity in the LSJR and their concentrations at two points in the LSJR. The salinity level in water can be measured as total dissolved solids (TDS). TDS is a measure of the quantity of dissolved solids in a given volume of water and it is determined by filtering and then evaporating a known volume of water and weighing the remaining solids. It is reported in terms of weight of solids per volume of water, such as milligrams per liter (mg/L). EC can be measured and used as surrogate for TDS. EC (which is also referred to as specific conductance) measures the transmission of electricity through water and is reported in units of µS/cm. There is a close correlation between TDS and EC; EC readings increase as salt levels increase. TDS (in mg/L) to EC (in µS/cm) ratios for the Lower San Joaquin River from Lander Avenue to the Airport Way Bridge near Vernalis range from 0.590 to 0.686 (SWRCB, 1987) and 0.65 is typically used as the multiplier to convert from EC to TDS.

Table 2-3: Average General Mineral Concentrations in the LSJR at Hills Ferry Road and at Airport Way, October 1995 - June 1998

		Airport Way Bridge near Vernalis (mg/L)	**Hills Ferry Road near Newman** (mg/L)
Cations			
Calcium	Ca	23	55
Magnesium	Mg	11	28
Sodium	Na	22	73
Potassium	K	2.7	4.6
Anions			
Bicarbonate	HCO_3	57	101
Sulfate	SO_4	62	224
Chloride	Cl	53	157

2.3 Salinity Impact Levels

A literature review was conducted to provide a scientific basis for setting salinity objectives. The results are presented in a draft staff technical report entitled *Salinity: A Literature Summary for Developing Water Quality Objectives* (Davis, 2000a). The most salt sensitive beneficial uses are drinking water, irrigated agriculture, and industrial uses. Other beneficial uses, such as fish and aquatic life, waterfowl, poultry, and livestock uses, while impacted by increasing salinity levels, are more tolerant to salinity.

In agricultural settings, irrigation with saline water can lead to the accumulation of salts in the soil profile over a period of time. Crop yield reduction occurs when salts accumulate in the root zone of the crop to the extent that the crop, through a reversed osmotic potential, is no longer able to extract sufficient water from the salty soil solution, resulting in water stress. If water uptake is appreciably reduced, the crop plant slows its rate of growth resulting in reduction of crop yield. Symptoms of salt toxicity are similar to those for plants under drought conditions, such as wilting, or a darker bluish-green leaf color, and occasionally thicker, waxier leaves (Ayers and Westcot, 1985). The August 1987 State Water Board Order No. 85-1 Technical Committee Report titled *Regulation of Agricultural Drainage to the San Joaquin River* presents an evaluation of water quality issues specific to the LSJR. It recommends a criterion of 700 µS/cm to fully protect irrigated agriculture and indicates that salinity at or below this level should protect other beneficial uses, such as stock watering, fish, and wildlife. The criterion was intended to fully protect all crops on all soil types in the LSJR basin and the southern Delta, if adequate drainage is provided.

Excess dissolved solids in drinking water can result in adverse physiological effects, unpalatable tastes, and higher costs from corrosion to pipes (U.S. EPA 1976; 1986). Sodium sulfate can produce laxative effects and sodium is thought to increase risk of heart disease. McKee and Wolf (1963) indicates that the salt concentration of good, palatable water should not exceed 500 mg/L. The Environmental Health Law under California Code Regulations (CCR) Title 22, Article 16, recognizing that salinity and other constituents may adversely affect the taste, odor, or appearance of drinking water, recommended a secondary maximum contaminant level (MCL) of 500 mg/L TDS or 900 μmhos/cm EC with an upper limit of 1,000 mg/L TDS or 1,600 μS/cm EC. This MCL is applied to community water systems administered by the California Department of Health Services and is referenced for domestic and municipal water supply use in the Regional Board's Basin Plan water quality objectives chapter (Davis, 2000).

According to McKee and Wolf (1963), dissolved solids in industrial water supplies can result in foaming inside boilers and interfere with clearness, color, or taste of many finished products. Elevated concentrations of salts also can accelerate corrosion. Concentrations from 50 to 3,000 mg/L dissolved solids have been recommended for waters used in specific industrial processes.

2.4 Pollutant Properties: Boron

Boron is a rare element widely distributed and bound to oxygen in nature. According to the European Centre for Ecotoxicology and Toxicology of Chemicals, boron is always found in the environment as inorganic borates because of its high affinity for oxygen (ECETOC, 1997). Its average concentration in the earth's crust is 0.001% (Mason and Moore, 1982). Absent in the elemental form in nature, boron normally occurs in mineral deposits as sodium borate (borax) or calcium borate (colemanite), and is found mostly in sedimentary deposits and sediments but also in metamorphic and igneous rocks. Its occurrence in sedimentary material is highly variable, with generally higher concentrations in marine deposits than in lacustrine and fluvial sediments (Perry and Suffet, 1994). Boron in seawater has concentrations typically of 5 mg/L (ECETOC, 1997).

Boron chemistry in fresh water approximates that observed in pure water. In most cases boron is trivalent (Nemodruk and Karalova, 1969). Its fundamental chemistry involves two chemicals, boric acid $B(OH)_3$ and borate or boric oxide ($B_2 O_3$). The equilibrium chemistry between the two compounds is:

$$B_2O_3 \leftrightarrows HBO_2 \leftrightarrows B(OH)_3$$

Water (H_2O) drives the equation to the right. Boric acid is moderately soluble in water and solubility increases substantially with increasing temperature (Perry and Suffet, 1994). Chemical speciation varies with acidity according to the following equilibrium equation:

$$B(OH)_3 + H_2O \leftrightarrows B(OH)_4^- + H^+$$

For basic conditions at a pH of approximately 8, which is characteristic of most natural waters, including the Lower San Joaquin River, the concentration of boric acid $B(OH)_3$ will be approximately 20 times greater than the borate ion $B(OH)_4^-$. Boron chemistry in fresh water involves these two chemicals, $B(OH)_3$ and $B(OH)_4^-$. Boric acid accounts for approximately 95% of the total dissolved boron in freshwater systems; the borate ion is approximately 5% (Perry and Suffet, 1994). Both compounds adsorb on clays and oxide surfaces (Keren and Bingham, 1985).

2.5 Boron Impact Levels

A Regional Board staff report titled *Boron: A Literature Summary for Developing Water Quality Objectives* (Davis, 2000b) reviews and summarizes information on the effects of boron on beneficial uses. Based on this review, the most sensitive beneficial uses (agriculture, aquatic life and municipal supplies) may be impacted by boron concentrations in the range of 0.5 to 2.0 mg/L.

Boron toxicity in plants is characterized by leaf malformation (such as leaf cupping in young grape leaves), and by thickened, curled, wilted, and chlorotic leaves (California Fertilizer Association, 1995; Maas, 1990). Some sensitive fruit crops, such as stone fruits, developed twig dieback and gummosis when exposed to toxic levels rather than exhibiting leaf injury. Some crops may exhibit leaf injury with reduced yields at low boron concentrations (Maas and Gratten, 1999).

Crop damage caused from boron contamination varies significantly with crop type. Studies indicate that boron sensitive crops such as apricots, avocados, oranges, and pecans may be affected at boron concentrations as low as 0.5-0.75 mg/L (Maas, 1990). These tolerances are based on leaf damage to young seedlings and experience in growing tree and vine crops in California suggests that extrapolation from leaf damage to yield reduction may not be appropriate and that the boron thresholds given above for citrus and avocados are very conservative (Oster, 1997). More boron tolerant crops, such as asparagus, cotton and onions can tolerate boron concentrations at or above 6.0 mg/L. The U.S. EPA (1986) has an agricultural water quality criterion for boron of 0.75 mg/L to protect sensitive crops during long-term irrigation (Marshack, 1998). Ayers and Westcot (1985) show a concentration of 0.7 mg/L boron in water would require no restriction for agricultural use.

The U.S. EPA published a 0.63 mg/L boron level in the Integrated Risk Information System (IRIS) as a reference dose for drinking water. This number was rounded down to 0.60 mg/L as the U.S. EPA drinking water health advisory or suggested no-adverse-response level (SNARL) for toxicity other than cancer risk. The California State action level for boron is 1.0 mg/L, based on a 1988 risk assessment document. These recommended levels are for drinking water supplies. No federal or state drinking water MCL has been established for boron.

Aquatic life sensitivity to boron varies widely by species. The literature suggests that a concentration of 0.75 to 1.0 mg/L is a reasonable environmentally acceptable limit for boron in aquatic systems (Davis, 2000). This level is based in part on laboratory and field studies on rainbow trout (Black, *et al.,* 1993), which is a particularly boron sensitive species.

2.6 Salinity And Boron Targets

Although the Regional Board is currently evaluating revised salinity and boron water quality objectives for the LSJR as part of developing a Basin Plan Amendment, no new objectives have yet been established. This TMDL, therefore, will use the existing water quality objectives at Vernalis as Numeric Targets. The existing water quality objectives have been established to protect the most sensitive beneficial use, which is principally agriculture. Some crops grown in the basin, including beans, can be impacted by salinity levels as low as 700 µS/cm during certain times of the year. The irrigation season (1 April – 31 August) Numeric Target for salinity is 700 µS/cm. The non-irrigation season water quality objective for salinity is 1,000µS/cm. These water quality objectives are the same numeric objectives set by the State Water Board for Delta waters at the intakes to the California Aqueduct and the DMC. Both the State and Federal water projects (canals) supply irrigation, municipal, wetland and aquatic habitat water for extensive areas south of the Delta, including portions of the LSJR basin. These objectives have been adopted by the State Water Board and approved by U.S. EPA and have thus been determined to provide reasonable protection of these beneficial uses.

The Regional Board has established numeric water quality objectives for boron for the LSJR between Sack Dam and the Airport Way Bridge near Vernalis (Table 2-2). Though the U.S. EPA has never approved the Regional Board's boron objectives, the EPA has not promulgated any new boron objectives for the LSJR.

As mentioned above, the Regional Board has been directed by the State Board to establish salinity water quality objectives for the LSJR upstream of Vernalis. Consequently, the Regional Board is currently in the process of preparing a Basin Plan Amendment to address salt and boron impairment in the LSJR to fulfill the Regional Board's mandate to develop water quality objectives for the LSJR. The existing boron objectives will be reviewed as part of the ongoing Basin Plan Amendment process to establish new salinity objectives. Regional Board staff held a series of three public workshops during the spring and summer of 2000 to present a range of water quality objectives for the salinity and boron in the LSJR from the Mendota Pool to Vernalis. These workshops generated extensive public comments regarding the suitability of the range of salt and boron objectives that were presented and the beneficial use designations for certain reaches of the LSJR. These comments raised significant technical and policy issues that must be further evaluated before proceeding with the Basin Plan Amendment to establish new or revised objectives for salt and boron.

Absent new or revised salt and boron water quality objectives for the LSJR at Vernalis and for the LSJR upstream of Vernalis, the existing monthly mean boron water quality objectives for the LSJR at Vernalis will be used as Numeric Targets in this TMDL (Table 2-4). These targets will be applied only to the LSJR near Vernalis. Similarly, the existing salinity objective for the San Joaquin River at Vernalis will be used as the salinity Numeric target in this TMDL. Additional numeric targets will be applied to reaches upstream of Vernalis when the Regional Board adopts new water quality objectives.

Table 2-4: TMDL Numeric Targets for LSJR at Vernalis

Paramenter	Season	
	Irrigation Season (Apr1-Aug31 salinity) (Mar15-Sep15 boron)	Non Irrigation (Sep1 –Mar 31salinity) (Sep16-Mar14 boron)
Salinity (EC) †	**700 µS/cm**	**1,000 µS/cm**
Boron††	**0.8 mg/L**	**1.0 mg/L**

†expressed as maximum 30-day running average, †† expressed as monthly mean

3.0 SOURCE ANALYSIS

3.1 Purpose

This source analysis is intended to identify the major sources of salt and boron loading to the LSJR and to characterize the relative loading from each of the identified sources. The source analysis ensures that all pollutant sources have been considered and facilitates the development of TMDL load allocations by focusing control actions and load reductions on the appropriate sources. The source analysis may also be used to identify responsible parties associated with each of the identified sources.

3.2 Overview

The source analysis for the LSJR Salinity and Boron TMDL is comprised of four major components:

1) A description of the mass emissions from the LSJR as measured at the Airport Way Bridge near Vernalis is given in section 3.3.

2) A geographic analysis that apportions the LSJR watershed into component geographic sub-areas is given in section 3.4.

3) A discussion of types or categories of pollutant sources in the watershed is given in section 3.5.

4) A summary and evaluation of the salt and boron loads that are attributable to the non-point sources which comprise the majority of controllable salt loads to the LSJR is given in section 3.6.

This source analysis is based on numerous data, methods, and assumptions that are described in more detail in a series of 5 appendices. Supporting information on load calculation methods and data is given in Appendix A. The Geographic Information System (GIS) processing information and metadata for the GIS coverages used in the source analysis are provided in Appendix B. The methods and data used to calculate salt loading from municipal and industrial point sources is contained in Appendix C. The methods used to estimate background salt and boron loading to the LSJR are in Appendix D. Alternate methods for calculating salt loading from the Northwest Side of the LSJR are described in Appendix E.

3.3 Lower San Joaquin River Mass Emissions

The LSJR at the Airport Way Bridge near Vernalis is the downstream boundary of the salt and boron 303(d) listed impairment. It is also upstream of the tidal influence of the Delta. Furthermore, the Vernalis site is the most upstream river location where salinity water quality objectives have been established. Salt and boron loads at Vernalis are equal to the total load from the entire TMDL project area or the sum of the individual loads from each of the contributing sub-areas.

The mean annual discharge of the LSJR at the Airport Way Bridge near Vernalis gaging station was approximately 3.7-million acre-feet (MAF) from water-years 1977 through 1997 (Figure 3-1). The mean annual salt mass emissions from the LSJR basin was approximately 1.1 million tons for water years 1977 through 1997. Mass annual salt emissions from the LSJR ranged from a minimum of approximately 442 thousand tons in water-year 1977 to a maximum of approximately 2.7 million tons in water-year 1983 during this 21-year period of record (Figure 3-2).

The Vernalis gaging station, which was established in 1922, is operated by the USGS and provides a good long-term daily flow record for the LSJR at Vernalis (USGS, 1997). The USGS also collects daily specific conductance data at the Vernalis gaging station. Monthly flow data were used in conjunction with flow-weighted monthly specific conductance data to calculate the monthly and annual mass salt loading for the San Joaquin River at the Airport Way Bridge near Vernalis.

Boron mass emissions were also calculated using the same USGS flow data from the Vernalis gage and water quality data collected by the Regional Board. The mean annual boron mass emissions from the LSJR basin were approximately 975 tons per year for water years 1977 through 1997. Boron emissions range from a low of approximately 360 tons per year in 1977 to a high of approximately 2,300 tons per year in 1983 (Figure 3-3).

Salt and boron mass emissions from the LSJR characterize the total pollutant loading from the entire TMDL project area. These mass emissions, however, do not identify the specific sources of pollution within the LSJR basin. In order to identify the pollutant sources, the watershed must be discretized into its component sub-watersheds and the mass loading from each sub-watershed must be determined to identify areas contributing the largest quantities of pollution relative to the total LSJR basin mass emissions. Except for losses due to evapotranspiration, evaporation, groundwater seepage, and diversions for agricultural supplies, the total mass loading from each sub-watershed should equal the mass emissions at Vernalis.

Figure 3-1: LSJR Annual Discharge at Vernalis

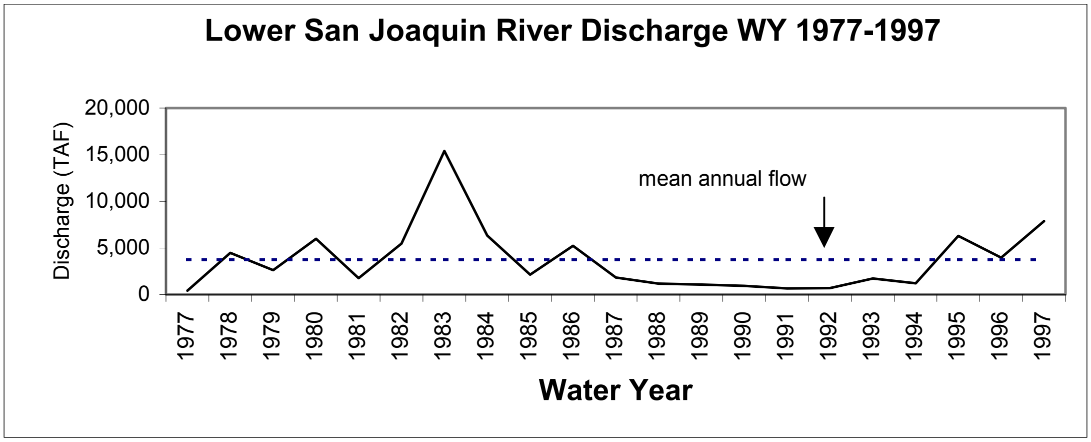


Figure 3-2: LSJR Annual Salt Emissions at Vernalis

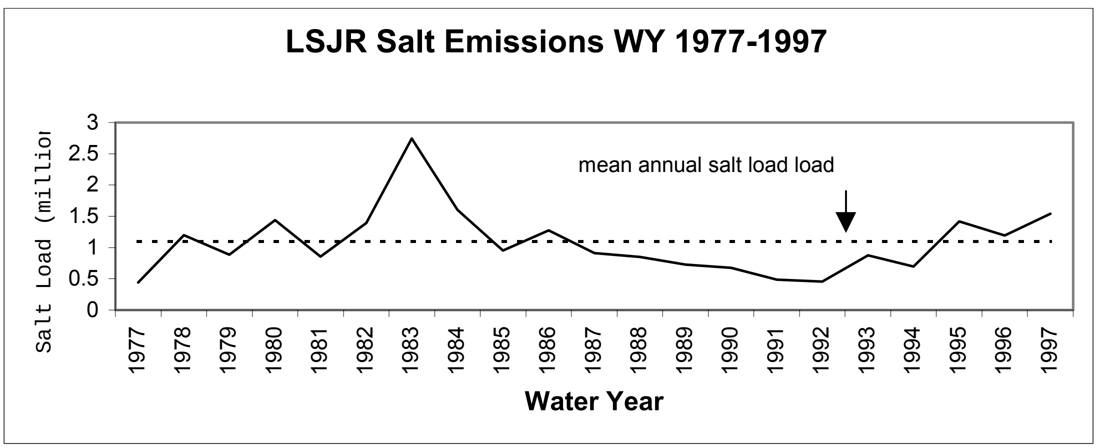
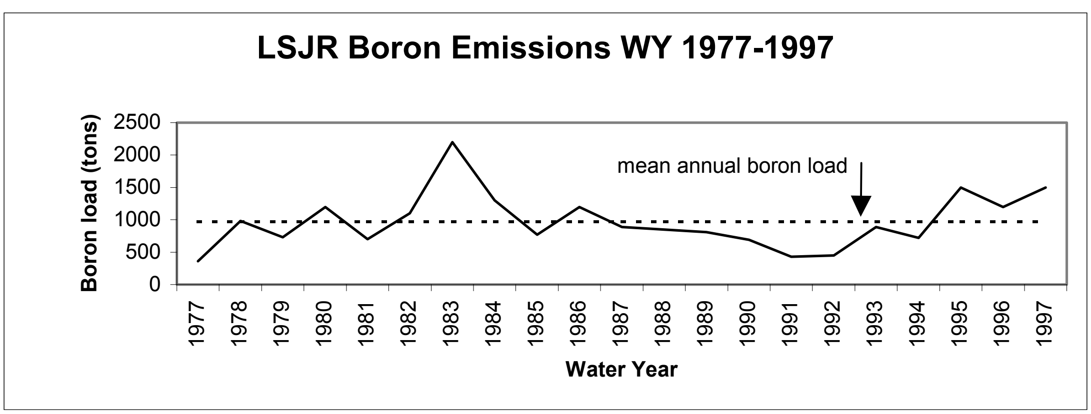


Figure 3-3: LSJR Annual Boron Emissions at Vernalis



3.4 Geographic Analysis

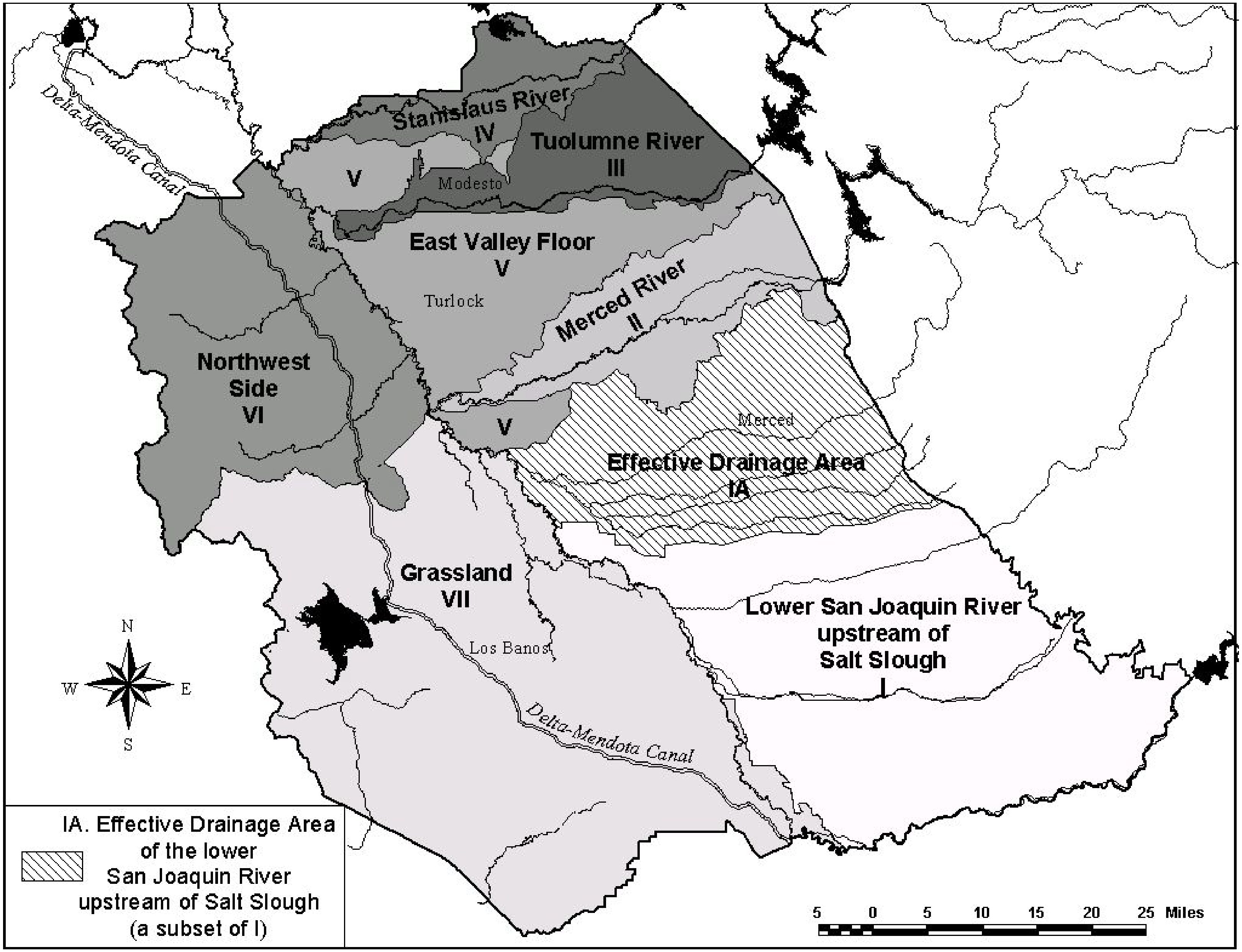
The geographic analysis heavily relies on existing spatial data developed by outside agencies, including the DWR, USGS, U.S. EPA, and the U.S. Bureau of Reclamation (USBR). Information describing the sources of the spatial data and GIS processing information (metadata) is given in Appendix B.

For TMDL planning purposes the LSJR watershed has been divided into seven major geographic sub-areas (Figure 3-4, Table 3-1). Unlike most natural watersheds, the LSJR river watershed cannot be broken down into its component sub-watersheds solely by using surface elevation data because the San Joaquin valley floor is relatively flat and water supply management has significantly altered natural drainage patterns. Elevation changes in the valley floor are so subtle that water is easily transferred from one sub-watershed to another. Therefore, the term sub-area, instead of sub-watershed, is used here to describe the geographic units evaluated in this source analysis. A GIS was used to delineate and assess the characteristics of each sub-area. The seven sub-area delineations are based on both the geographic distribution of available monitoring data and common physiological characteristics. In addition to these seven geographic source areas, the DMC, the region’s primary water supply conveyance, is another major source of salt that is also discussed in the geographic analysis.

Table 3-1: Geographic Sub-areas

Sub-area Name		Description
I.	LSJR upstream of Salt Slough	This sub-area drains 1,476 square miles on the east side of the LSJR upstream of the Salt Slough confluence. The sub-area includes the portions of the Bear Creek, Chowchilla River and Fresno River watersheds that are contained within Merced and Madera Counties. The northern boundary of the sub-area generally coincides with the Merced River drainage area. The western and southern boundaries follow the San Joaquin River from the Salt Slough confluence to Friant, except for the lands within the Columbia Canal Company which are excluded. Columbia Canal Company lands are included in the Grassland Sub-area
Ia.	Effective Drainage Area of LSJR upstream of Salt Slough	This is a 523-square-mile subset of lands within the LSJR upstream of the Salt Slough Sub-area. This area is predominantly comprised of the portion of the Bear Creek Watershed that is contained within Merced County.
II.	Merced River	This sub-area is comprised of the Merced River watershed downstream of the Merced-Mariposa county line. The sub-area is 281 square miles in size.
III.	Tuolumne River	This sub-area is comprised of the Tuolumne watershed downstream of the Stanislaus-Tuolumne county line. The sub-area is 253 square miles in size.
IV.	Stanislaus River	This sub-area is comprised of the Stanislaus River watershed downstream of the Stanislaus-Calaveras county line. The sub-area is 152 square miles in size.
V.	East Valley Floor	This sub-area includes 476 square miles of land on the east side of the LSJR that drains directly to the LSJR between Vernalis and the Salt Slough confluence. The sub-area is largely comprised of the land in between the major east-side drainages of the Tuolumne, Stanislaus, and Merced Rivers. This sub-area lies within eastern Stanislaus County and northeastern Merced County. Numerous drainage canals, including the Harding Drain, and natural drainages drain this sub-area.
VI.	Northwest Side	This sub-area is 603 square miles in size. The Northwest Side Sub-area generally includes the lands on the West side of the LSJR from Vernalis to the LSJR's confluence with the Merced River. This sub-area includes the entire drainage area of Orestimba, Del Puerto, and Hospital/Ingram Creeks. The eastern Boundary of the sub-area follows the LSJR from Vernalis to the Merced River confluence and the western boundary follows the crest of the Coast Range. The sub-area is primarily located in Western Stanislaus County except for a small area that extends into Merced County in the vicinity of Gustine and the CCID Main Canal.
VII.	Grassland	The Grassland Sub-area encompasses 1,360 square miles on the west side of the LSJR in portions of Merced, Stanislaus, and Fresno Counties. This sub-area is includes the Mud Slough, Salt Slough, and Los Banos Creek watersheds. The western boundary of this sub-area is generally formed by the LSJR from upstream of the Merced River confluence to downstream of the Mendota Pool. The Grassland Sub-area extends across the LSJR, to the east side of the San Joaquin Valley, to include the lands within the Columbia Canal Company's jurisdiction. The Columbia Canal Company was included in the Grassland Sub-area because it receives supply water from the Mendota Pool and it's drainage is eventually discharged into the Grassland Sub-area in supply water diverted at Sack Dam. The eastern boundary of the sub-area generally follows the crest of the Coast Range except for the lands within San Benito County on the east-side of the Coast Range which have been excluded.

Figure 3-4: Lower San Joaquin River Sub-areas



Delta Mendota Canal (DMC)

The DMC is a major water supply conveyance that delivers water to Lower San Joaquin Valley irrigators. The DMC was included in the geographic analysis because DMC deliveries strongly influence the pollutant loading from two of the major sub-areas within the LSJR watershed. A basic understanding of LSJR water management is integral to understanding the hydrology that influences the discharge characteristics of each of the LSJR sub-areas.

In 1942 the USBR completed the Friant Dam on the San Joaquin River (USBR, 2001). Millerton Lake, the impoundment behind Friant Dam, is located approximately 63 miles upstream of the Mendota Pool. The majority of San Joaquin River flows are diverted out of the San Joaquin Basin to the Tulare Lake Basin at Millerton Lake. This has resulted in a significant de-watering of the San Joaquin River downstream of the dam. As a result, the USBR entered into an ongoing water Exchange Contract with the Lower San Joaquin Valley irrigators in order to satisfy the existing water rights that were impinged upon by out of basin diversions from the SJR at Millerton Lake. Under the Exchange Contract, the Lower San Joaquin Valley irrigators are supplied with water from the Delta in exchange for water that is now diverted to the south out of the river basin at the Friant Dam.

The DMC is the primary facility that is used to implement the Exchange Contract by replacing and supplementing the natural river flows that were diverted out of the San Joaquin Basin at Friant. The DMC was completed in 1951 and conveys water from the Tracy Pumping Plant in the South Delta to the Mendota Pool. The DMC is about 117 miles long and has an initial diversion capacity of 4,600 cfs, which gradually decreases to 3,211 cfs at the canal's terminus at the pool (USBR, 2001).

The DMC supplies a volume of water that is roughly equal to the average water delivered to the exchange contractors directly from the SJR prior to the diversion SJR water out of the basin. The DMC exchange water, however, provides a much greater salt load than was previously provided by the SJR due to the relatively high salinity of Delta water.

The DMC contributed approximately 47 percent of the LSJR's total salt load at Vernalis between 1977 and 1997 (Table 3-2). Water users receive deliveries directly from the DMC and from the Mendota Pool. Altogether, DMC water is currently being delivered to about 36 agricultural, municipal, and wetland water users in the LSJR basin. The imported DMC salt load is distributed to the water users in their supply water. These water users are geographically spread out over the LSJR basin and imported DMC salt is indirectly discharged to the LSJR when return flows discharge to the river. Salt loads being delivered from the DMC to the LSJR geographic sub-areas must therefore be elucidated from salt loads generated within these affected sub-areas. In this context, the DMC is effectively a non-point source of salt within each of the sub-areas that it supplies.

Table 3-2: DMC Salt Contributions by Sub-area 1977-1997 (thousand tons)			
Sub-Area	DMC salt load (imported)	Total Sub-area salt load (emissions)	Percent of Sub-area salt load originating from DMC
Grassland	423	400	100+%
Northwest Side of the SJR	90	320	28%
TOTAL LSJR at Vernalis	513	1,100	47%

Sub-area I. LSJR Upstream of Salt Slough to the Mendota Pool

The LSJR upstream of Salt Slough is the largest sub-area in the TMDL project area and it occupies approximately 945,000 acres in western Madera and eastern Merced counties with a small portion in Mariposa County. The cities of Atwater, Madera, Merced, Le Grand and Chowchilla are located within this sub-area. Hydrologically, this sub-area originates at the Mendota Pool. The Mendota Pool is an in-stream impoundment on the LSJR that receives water from the DMC. The majority of flow in the San Joaquin River upstream of the Mendota pool is diverted out of the San Joaquin River at the Friant Dam. Until recently, much of the reach of the San Joaquin River from Friant Dam to the Mendota Pool has been dry. Releases from Friant were only sufficient to provide minimal irrigation water supplies. Starting in 1999 water has been released at Friant Dam and discharged into the Mendota Pool in an effort to restore upstream riparian areas. The Mendota Pool also receives supply water from the DMC and to a lesser extent from upstream releases made during extremely wet weather. The southeastern portion of the sub-area (including Chowchilla and Madera Irrigation Districts) also receives high quality irrigation supply water from Millerton Lake via the Madera Canal. Most of the water released from the Mendota Pool and any irrigation return flows to the river are diverted out of the LSJR approximately 22 miles downstream of the Mendota Pool at the Sack Dam for irrigation supplies. During the irrigation season, the LSJR is again dry from Sack Dam to near it's confluence with Bear Creek. Bear Creek is the principal LSJR tributary that drains this sub-area. The Fresno and Chowchilla Rivers also drain large portions of the sub-area but rarely contribute flows to the LSJR except during flood periods.

Sub-area Ia. Effective Drainage area of LSJR Upstream of Salt Slough

Flow and water quality are monitored on the LSJR at Lander Avenue to characterize discharges coming from the LSJR upstream of Salt Slough Sub-area. Although the LSJR upstream of Salt Slough Sub-area encompasses 945,000 acres, not all of the drainage from this land flows to the LSJR at Lander Avenue. Groundwater levels in large portions of this sub-area are depressed because of extensive pumping and the presence of relatively well-drained soils. As a result, much of the water applied to crops in this sub-area infiltrates to groundwater and never directly discharges to the LSJR. Most of the drainage that enters the LSJR upstream of the Sack Dam is diverted out of the river and applied to crops outside of the sub-area. The LSJR typically remains dry for another 20 to 30 miles downstream of Sack Dam. For these reasons, a 335,000-acre subset of lands within the LSJR upstream of Salt Slough Sub-area that actually drain to the LSJR at

Lander has been delineated. This subset of land is referred to as the "effective drainage area" of the LSJR upstream of Salt Slough.

This sub-area discharges an average of approximately 860,000 acre-feet of water per year (WYs 77-97) which accounts for about 23 percent of the rivers total flow at Vernalis. The LSJR upstream of Salt Slough Sub-area contributed an average of about 100,000 tons of salt per year and 66 tons of boron to the LSJR during water years 1977-1997. This only represents about 9 percent of the river's total salt load and 7 percent of the rivers total boron load. Most of the flow and salt load occurs during high flow flood periods

a. Water Districts:
The Aliso, Chowchilla, Clayton, El Nido, Farmers', Gravelly Ford, Le Grande-Athlone, Madera, Merced, New Stone, Plainsburg, Root Creek, Sierra, and Turner Island water and irrigation districts are mostly or completely contained within the LSJR upstream of Salt Slough Sub-area. Additionally, a small portion of Merquin County Water District is also contained within the sub-area.

b. Agricultural Land Use/Non-point Sources:
Based on DWR Land Use Information Survey data collected between 1994 and 1997, the Lower San Joaquin River upstream of Salt Slough Sub-area contains approximately 561,000 acres of agricultural lands making this sub-area not only the largest in total land area but also the largest in agricultural land area. However, the effective drainage area of the LSJR upstream of Salt Slough contains approximately 149,000 acres of agricultural land. The effective drainage area of the LSJR upstream of Salt Slough also contains approximately 35,000 acres of managed wetlands (Grasslands Ecological Area). The full sub-area also contains approximately 49,000 acres of urban land use.

c. Permitted Discharges/Point Sources:
The cities of Atwater and Merced in the northern portion of the San Joaquin River above Salt Slough Sub-area are the only significant sources of Municipal or Industrial (M&I) salt discharge. Atwater and Merced discharge approximately 1,800 and 4,300 tons of salt per year, respectively (Appendix C). Discharges to surface waters from both of these wastewater treatment facilities is intercepted and diverted back out for irrigation and other uses before reaching the LSJR. Therefore, these wastewater treatment plants have no direct discharge salt and boron to the LSJR.

Sub-area II. Merced River downstream of Lake McClure
The Merced River Sub-area is designated as the watershed of the Merced River downstream of Lake McClure and the Merced County line. The Merced River Sub-area is approximately 180,000 acres in size and is almost entirely within the northern portion of Merced County, although small portions of the sub-area exist in eastern Stanislaus County. The communities of Hilmar, Delphi, and Livingston are located with this sub-area. Similar to both the Tuolumne and Stanislaus Rivers, the Merced River discharges high quality water to the LSJR. The Merced River' contributes approximately 15 percent of the LSJR's total annual flow, 4 percent of the river's annual total salt load and 1

percent of the rivers total boron load. On average this sub-area discharges approximately 549,000 acre-feet of water, 48,000 tons of salt, and 14 tons of boron per year to the LSJR.

a. Water Districts:
The Ballico-Cortez Water District and Eastside Water District are almost entirely within the Merced River Sub-area. Additionally, small portions of Merced Irrigation District, Stevinson Water District, and Turlock Irrigation District are located within the sub-area.

b. Agricultural Land Use/Non-point Sources:
Based on DWR Land Use Survey Information Survey data collected between 1994 and 1997, the Stanislaus River Sub-area contains approximately 94,000 acres of agricultural land use and approximately 8,670 acres of urban land use.

c. Permitted Discharges/Point Sources:
There are no significant M&I discharges within the Merced River Sub-area.

Sub-area III. Tuolumne River downstream of New Don Pedro Reservoir

The Tuolumne River Sub-area is defined as the drainage area of the Tuolumne River downstream of New Don Pedro Reservoir and the Stanislaus County line. The Tuolumne River Sub-area is approximately 162,000 acres in size and is entirely contained within the east-central portion of Stanislaus County. The community of Waterford and a portion of Modesto are located within the sub-area.

The Tuolumne River is characteristic of the east-side LSJR tributaries and generally has excellent water quality, although some degradation of water quality results from agricultural use within the sub-area. The Tuolumne River contributes 27 percent of the LSJR's total flow, 9 percent of the river's total salt load, and 3 percent of the river's total boron load. On average this sub-area discharges approximately 994,000 acre-feet of water, 92,000 tons of salt, and 25 tons of boron per year to the LSJR.

a. Water Districts:
Portions of Modesto Irrigation District, Oakdale Irrigation District, and Turlock Irrigation District are contained within the Tuolumne River Sub-area.

b. Agricultural Land Use/Non-point Sources:
Based on DWR Land Use Survey Information Survey data collected between 1994 and 1997, the Stanislaus River Sub-area contains approximately 52,000 acres of agricultural land use and approximately 17,200 acres of urban land use

c. Permitted Discharges/Point Sources:
There are no significant M&I discharges within the Stanislaus River Sub-area.

Sub-area IV. Stanislaus River downstream of New Melones Reservoir

The Stanislaus River Sub-area is the watershed of the Stanislaus River downstream of the New Melones Reservoir and the Stanislaus County line. The Stanislaus River Sub-area is approximately 97,000 acres in size and is almost completely within northern Stanislaus County, although a small portion of the sub-area exists in southern San Joaquin County. The Communities of Oakdale, Riverbank and Salida are located in this sub-area.

The Stanislaus River Sub-area receives high quality water from the western Sierra Nevada. Though some degradation of water quality can occur from land and water uses within the sub-area, the river generally provides high quality dilution flow to the LSJR. Although the Stanislaus River contributes 18 percent of the LSJR's total flow, it only accounts for about 6 percent of the river's total salt load and 2 percent of the river's total boron load. On average this sub-area discharges approximately 678,000 acre-feet of water and about 60,000 tons of salt per year to the LSJR.

a. Water Districts:

Oakdale and South San Joaquin Irrigation Districts are almost entirely within the sub-area. Additionally, a small portion of Modesto Irrigation District is also contained within the sub-area.

b. Agricultural Land Use/Non-point Sources:

Based on DWR Land Use Survey Information Survey data collected between 1994 and 1997, the Stanislaus River Sub-area contains approximately 53,000 acres of agricultural land use and approximately 12,900 acres of urban land use.

c. Permitted Discharges/Point Sources:

No M&I discharges occur in the Stanislaus River Sub-area.

Sub-area V. East Valley Floor

The East Valley Floor Sub-area is the east side of the San Joaquin Valley that drains directly to the LSJR. It lies between the Stanislaus, Tuolumne, and Merced River watersheds. As a result, the sub-area is divided into three pieces, one large central piece between the Tuolumne and Merced watersheds and two smaller pieces, one to the north between the Stanislaus and Tuolumne watersheds, and one to the south between the Merced River and Bear Creek watersheds. The East Valley Floor Sub-area is approximately 305,000 acres and it is located largely within central Stanislaus County with smaller portions of the sub-area in southern San Joaquin, and northern Merced counties. The cities of Turlock, Salida, Ceres, Denair and Keyes are located within the East Valley Floor Sub-area. Portions of Modesto and Hilmar are also located within the sub-area.

The majority of agricultural water supplied to the East Valley Floor Sub-area comes form stored Sierra Nevada runoff and is generally of excellent quality (low salinity and boron). Portions of the East Valley Floor Sub-area experience elevated groundwater levels and as a result seasonal shallow groundwater is strategically pumped in an attempt to lower the groundwater table below crop rooting depths. The pumped groundwater is typically discharged into canals where it is mixed with surface water supplies and used for irrigation supply within the sub-area or discharged to the LSJR (Liebersbach, personal communication, 2001). The East Valley Floor drains directly to the LSJR primarily through a network of irrigation and drainage canals. These drainage canals receive a combination of discharges from agricultural surface returns, urban runoff, groundwater pumping, intercepted groundwater, and natural stream flows.

Estimates of discharges from the East Valley Floor Sub-area indicate that the sub-area contributes roughly 3 to 4 percent of the LSJR's total flow and about 5 percent of the river's total salt load and about 2 percent of the river's total boron load. On average this sub-area discharges approximately 149,000 acre-feet of water, 57,000 tons of salt, and 21 tons of boron per year to the San Joaquin River. These figures are based on limited data from the Harding Drain that was applied to the larger East Valley Floor Sub-area after accounting for wastewater treatment plant discharges (see Appendix A).

a. Water Districts:

The Merquin County Water District, Stevinson Water District, and Turlock Irrigation District are mostly or completely within the East Valley Floor Sub-area. Additionally, smaller portions of Eastside, Modesto, and Oakdale irrigation and water districts are also within the sub-area.

b. Agricultural Land Use/Non-Point Sources:

Based on DWR Land Use Survey Information Survey data collected between 1994 and 1997, the East Valley Floor Sub-area contains approximately 216,000 acres of agricultural land use and approximately 30,700 acres of urban land use.

c. Permitted Discharges/Point Sources:

The cities of Turlock and Modesto in the eastern portion of Stanislaus County both discharge directly to the LSJR via the East Valley Floor Sub-area. The cities of Turlock and Modesto discharge approximately 8,100 and 33,000 tons of salt respectively. These are the only direct discharges to surface waters from wastewater treatment facilities in the entire TMDL project area.

Sub-area VI. Northwest Side of the San Joaquin River

The Northwest Side Sub-area includes the entire drainage areas of the west side creeks, including Orestimba, Hospital, Ingram, Salado and Del Puerto Creeks. The northern most boundary of the sub-area includes portions of Lone Tree Creek. The Northwest Side Sub-area is approximately 386,000 acres in area and is almost entirely within western Stanislaus county, although small portions of the sub-area lie within southern San Joaquin County as well as northern Merced County where a seasonally flowing drainage canal, tributary to Orestimba Creek, reaches over the county line near the city of Gustine. The cities of Patterson and Newman are located within this sub-area.

The Northwest Side Sub-area receives a combination of irrigation supply water from the DMC, pumped groundwater, and LSJR diversions, all of which are relatively high in salts. The Coast Range drainages within this sub-area are also high in salts and boron (Westcot, 1991). The Northwest Side Sub-area contributes approximately 6 percent of the LSJR's total flow, 29 percent of the river's total salt load, and 35 percent of the river's total boron load. On average this sub-area discharges approximately 230,000 acre-feet of water, 320,000 tons of salt, and 340 tons of boron per year to the San Joaquin River.

a. Water Districts:
The Del Puerto Water District, El Solyo Water District, Oak Flat Water District, Patterson Irrigation District, and West Stanislaus Irrigation District are contained mostly or completely within the Northwest Side Sub-area. Additionally, small portions of Central California Irrigation District and Stevinson water districts are also within the sub-area.

b. Agricultural Land Use/Non-point Sources:
Based on DWR Land Use Survey Information Survey data collected between 1994 and 1997, the Northwest Side Sub-area contains approximately 119,000 acres of agricultural land use and approximately 4,678 acres of urban land use.

c. Permitted Discharges/Point Sources:
The cities of Newman and Patterson in the western portion of the Northwest Side Sub-area are the only significant sources of permitted M&I salt discharge. Newman and Patterson discharge approximately 3,500 and 1,600 tons respectively, however, these wastewater treatment facilities discharge to land with no direct discharge to surface waters.

Sub-area VII. Grassland Watershed
The Grassland Sub-area occupies approximately 871,000 acres in portions of Stanislaus Merced, and Fresno counties. Mud Slough (north) and Salt Slough are the principal drainage arteries for the Grassland Watershed. The Drainage Project Area (DPA) is a 97,000-acre tile drained agricultural area within the Grassland Sub-area that generates substantial amounts of saline subsurface drainage. Additionally, a 115,000-acre portion of the Grasslands Ecological Area (GEA) is also contained within the Grassland Sub-area. As mentioned above, the GEA is a conglomerate of private, state and federally owned and operated wetlands. The 52,250-acre Grassland Water District is the largest public water agency within the GEA. The cities Los Banos, Firebaugh, Dos Palos, Gustine, and South Dos Palos are located in this sub-area.

Most of the irrigation and wetland supply water for the Grassland Sub-area is imported from the Delta via the DMC. The water imported from the Delta is relatively high in salts and boron. Additionally, soils on the west side of the San Joaquin Valley are derived from rocks of marine origin in the Coast Range that are also high in salts and boron. Consequently, the discharge of agricultural surface and subsurface drainage and discharges from managed wetlands have resulted in elevated electrical conductivity and boron concentrations in Mud and Salt Sloughs. The Grassland Sub-area contributes approximately 6 percent of the LSJR's total flow, 37 percent of the river's total salt load, and 50 percent of the river's total boron load. On average this sub-area discharges approximately 230,000 acre-feet of water, 400,000 tons of salt, and 490 tons of boron per year to the San Joaquin River.

The average annual discharge from the Grassland Sub-area is approximately 210,000 acre-feet based on water-years 1977 through 1997. Discharge from the Grassland Sub-area accounts for approximately six percent of the river's total discharge as measured at Vernalis. The Grassland Sub-area contributes approximately 400,000 tons of salt per year to the LSJR, which accounts for approximately 36 percent of the rivers total salt load at Vernalis.

a. Water Districts:

Broadview Water District, Central California Irrigation District, Columbia Canal, Eagle Field Water District, Firebaugh Canal Water District, Grassland Water District, Laguna Water District, Lansdale Water District, Mercy Springs Water District, Oro Loma Water District, Panoche Water District, San Luis Canal Co., San Luis Water District, Santa Nella County Water District, and Wildren Water District are contained mostly or completely within the Grassland Sub-area. Additionally, a small portion of Del Puerto Water District is also located within the sub-area.

b. Agricultural Land Use/Non-point Sources:

Based on DWR Land Use Survey Information Survey data collected between 1994 and 1997, the Grassland Sub-area contains approximately 331,000 acres of agricultural land use and approximately 11,700 acres of urban land use. As mentioned above, approximately 115,000 acres of the GEA is contained the Grassland Sub-area. Approximately 15,000 acres of the 115,000-acre portion of the GEA contained in Grassland Sub-area are under agricultural production with the remaining 100,000 acres managed as wetlands.

c. Permitted Discharges/Point Sources:

The City of Gustine's wastewater treatment plant is the only significant source of M&I salt loads in the Grassland Sub-area, discharging approximately 2,700 tons of salt per year to land.

3.5 Source Categories

Regional Board staff has identified six major sources of salt and boron loading to the LSJR. These major sources include 1) the Sierra Nevada tributaries; 2) groundwater accretions; 3) municipal and industrial discharges; 4) wetland discharges 5) agricultural surface discharges; and 6) agricultural subsurface discharges.

I. Sierra Nevada Tributaries :

The Sierra Nevada tributaries evaluated in this report include the Merced, Tuolumne, and Stanislaus rivers. These rivers are also referred to as the "east-side tributaries" because they are the major tributaries of LSJR that flow from the east. The TMDL project area excludes the drainage areas of the major east-side tributaries upstream of the dams of major east-side reservoirs: New Don Pedro on the Tuolumne River, New Melones on the Stanislaus, and Lake McClure on the Merced. Collectively, these three rivers accounted for 2,220 acre-feet per year of the LSJR's total annual flow at Vernalis (based on WY 77-97); this accounts for about 60 percent of the total flow volume. Flows from the SJR upstream of Salt Slough accounted for an additional 860 acre-feet per year, for a total of approximately 3,100 acre-feet per year or 84 percent of the mean annual flow from the LSJR Watershed. The Sierra Nevada tributaries are relatively low in salts and in general provide high quality dilution flows to the LSJR. The flow weighted average TDS values for the Merced, Tuolumne, and Stanislaus Rivers, near their confluences with the LSJR, were 65mg/L, 68 mg/L, and 65 mg/L, respectively for water years 1977 to 1997. The flow weighted average TDS for the SJR upstream of Salt Slough was 85 mg/L.

Although the Sierra Nevada tributaries have low salt concentrations, they deliver significant salt loads as a result of their large discharge to the LSJR. Consequently, the Sierra Nevada tributaries contribute approximately 200,000 tons per year; the SJR upstream of Salt Slough contributes an additional 100,000 tons per year. Though some salt is generated from land and water uses within the tributary watersheds in the project area, the majority of the salt contributed to the LSJR by these rivers originates from flood flows and other background/ambient sources. Flood and background flows account for 222,000 tons (73 percent) of the total 300,000 tons discharged by the four tributaries. The remaining salt load is attributable to anthropogenic sources within the TMDL project area. Total versus background salt and boron loads for each of the Sierra Nevada Tributaries and SJR upstream of Salt Slough are presented in Table 3-7. The methods used to calculate total salt and boron loading from the Sierra Nevada tributaries are described in Appendix A. The methods used to calculate background and anthropogenic salt and boron loads from the Sierra Nevada Tributaries are described in Appendix D.

II. Groundwater Accretions:

Historically, the majority of groundwater recharge in the LSJR watershed occurred in the upland areas surrounding the San Joaquin Valley floor. Groundwater flow generally followed the valley topography flowing from high to low areas. Surface water recharge to groundwater primarily occurred in the upper elevation tributaries shortly after they enter the valley floor (USGS, 1997). Agricultural land use practices, however, have had a significant impact on groundwater flow and quality. Prior to the construction of the major water projects on the San Joaquin River, early irrigation practices included excessive groundwater pumping, which resulted in groundwater draw down and widespread land subsidence (SJVDP, 1990b). Under the current level of agricultural and water development, irrigation infiltration has replaced upland stream recharge as the predominant source of shallow groundwater recharge (USGS, 1997). Infiltration of applied water and canal leakage has resulted in a dramatic rise in the water table since the implementation of the Central Valley Project and rising water tables have necessitated installation and use of tile drains in some areas on the west side of the LSJR. In portions of the east side of the LSJR groundwater is pumped to draw the water table down below crop root zones (Liebersbach, personal communication, 2001).

Naturally occurring salts in San Joaquin Valley soils, as well as salts associated with surface water imports to the LSJR basin contribute to elevated salinity of the shallow groundwater. Application of irrigation water causes salt and boron to be leached from the soil profile and discharged to the shallow aquifer. Supply water imported from the Delta contains additional salts, which must be flushed from the root zone to maintain a salt balance. Only shallow groundwater pumping or discharge to the LSJR removes salt and boron that accumulates in the shallow groundwater.

Though groundwater accretion to the LSJR accounts for only about four percent of the mean annual LSJR flow at Vernalis, these high salinity accretions contribute substantial salt loads to the LSJR. A 1991 USGS Water Resource Investigation Report found that average groundwater accretion to the LSJR was approximately 2 cfs per mile for the 19-mile reach of the LSJR between Hills Ferry Road and Las Palmas Avenue. The report findings were based on a cross sectional groundwater-flow model using monitoring well data collected at three cross-sections. Additionally, a mass balance model based on synoptic studies conducted in 1986 and 1989 estimated groundwater discharge to be between 6.7 and 3.2 cfs per mile (USGS, 1991). According to the same 1991 USGS Water Resource Investigation Report, the average constituent concentrations for TDS and boron were 1,590 mg/L and 1,321 µg/L (1.3 mg/L), respectively. Average EC was found to be approximately 2,230 µS/cm, which indicates that the EC to TDS conversion factor is approximately 0.71. A previously developed salt loading model for the LSJR between Stevinson and Vernalis also estimated that average groundwater accretions to the LSJR were approximately 2 cfs per mile with an average EC of approximately 2,200µS/cm (SWRCB, 1987).

Model results from the 1991 USGS Water Resource Investigation Report indicate that there is an eastward flow of groundwater across the San Joaquin Valley trough. The groundwater divide between the east and west sides of the San Joaquin River is therefore located on the east side of the river, and groundwater from the west side flows below the LSJR to the east side of the valley. The percentage of groundwater from the shallow east side of the LSJR, the shallow west side of the LSJR, and the deeper aquifer flowing from the Coast Range were estimated by the USGS using a calibrated layered groundwater model at three sites along a 19-mile reach the LSJR. Flow-weighted average values from the three sites were applied to a 60-mile reach of the LSJR to estimate groundwater salt contributions to the river from the shallow east side, the shallow west side, and the deeper coast range aquifer (Table 3-3). Approximately 62 percent of the groundwater accretions and 87 percent of the ground water salt contribution to the LSJR comes from deeper Coast Range groundwater, with lesser amounts from shallow sources on the east and west side of the LSJR.

Table 3-3: Estimated Groundwater Accretions and Salt Contribution to the LSJR

Groundwater Component	**Flow-weighted Percent of total Flow**	**Flow * (cfs/mi)**	**TDS (mg/L)**	**Salt Load (tons/mi/year)**	**Salt Load (% of total)**
Sallow East Side	14%	0.29	698	199	6%
Sallow West Side	24%	0.49	438	211	7%
Deep-Coast Range	62%	1.26	2250	2792	87%
Total	**100%**	**2.04**	**1594**	**3,203**	**100%**

*** Based on a total mean annual flow of 2.04 cfs/mi (1,478 acre-feet per mile per year)**

Groundwater accounted for approximately 89,000 acre-feet and 192,000 tons of salt per year discharged to the LSJR, assuming an average accretion of 1,478 acre-feet per mile per year and salt loading value of 3,203 tons per mile per year over the sixty-mile reach of the LSJR between Lander Avenue and Vernalis. The 12 miles of Mud Slough and 28 miles of Salt Sloughs account for an additional 40 miles of source area. Assuming similar accretion rates and water quality, the groundwater contribution from these sloughs adds 59,000 acre-feet and 128,000 tons of salt per year. This suggests that groundwater accretions to the LSJR are approximately 148,000 acre-feet per year, representing four percent of the mean annual discharge. These accretions add 320,000 tons of salt per year or 30 percent of the mean annual salt load in the LSJR at Vernalis. This estimate does not account for the groundwater salt load component of the discharges from the east side Sierra Nevada tributaries of the LSJR. This groundwater analysis suggests that the groundwater salt loads from the Sierra Nevada tributaries will be relatively low due to the higher quality of east side groundwater accretions.

Limited data was available to develop groundwater salt load estimates. Actual annual loads will be significantly affected by variable rates of groundwater pumping and groundwater recharge.

III. Municipal and Industrial Discharges:

M&I discharges typically consist of treated wastewater discharged from municipal wastewater treatment facilities (sewage treatment plants) and private industries. In some cases industries are “connected” to wastewater treatment plants and industrial waste is treated along with domestic sewage before being discharged to land or surface waters. The majority of M&I discharges to the LSJR come from wastewater treatment plants. Wastewater treatment plant discharges are regulated by the Regional Board through Waste Discharge Requirements (WDRs) and National Pollutant Discharge Elimination System (NPDES) permits. The Regional Board has issued permits to eight wastewater treatment plants in the LSJR TMDL project area for the cities of Modesto, Merced, Turlock, Atwater, Patterson, Newman, Gustine, and Planada. The permits for Cities of Patterson and Newman, however, have been rescinded as these plants now only discharge to land. Additionally, there are 13 external industries (not connected to wastewater treatment plants) that are regulated under NPDES permits.

The municipal salt loads generated by the eight municipalities (and their connected industries) located in the lower San Joaquin River basin total about 55,000 tons/year. The average annual flow rates from these eight municipalities sums to about 55 Million-Gallon Day (MGD), or 62,000 acre feet/year. Only two of the eight wastewater treatment plants actually discharge to surface waters; the remaining six facilities discharge to land. For the purposes of this TMDL, only direct discharges to surface waters were considered. The annual wastewater flow rate discharged directly to the San Joaquin averages 25 MGD or 28,000 acre-feet per year (solely by Modesto and Turlock); this is only one percent of the mean annual discharge in the LSJR. Approximately 25,500 tons of salt per year are conveyed in this discharge; this accounts for approximately two percent of the LSJR’s mean annual salt load at Vernalis. The remaining 30,000 tons/year of salt is discharged to land or wetlands. Of the 25,500 tons/year of salt load discharged directly to the LSJR, 6,500 tons/year is discharged during the irrigation season of April through August, and 19,000 tons/year is discharged during the non-irrigation season of September through March. Approximately 7,000 tons/year of salt are discharged from the 13 external industries; these loads are not discharged to surface waters.

The flow rates and salt concentrations given above were determined by Regional Board staff, from NPDES self-monitoring data, from engineering reports, and from personal communications with plant operators. More detail on the methods used to determine M&I salt contributions can be found in Appendix C.

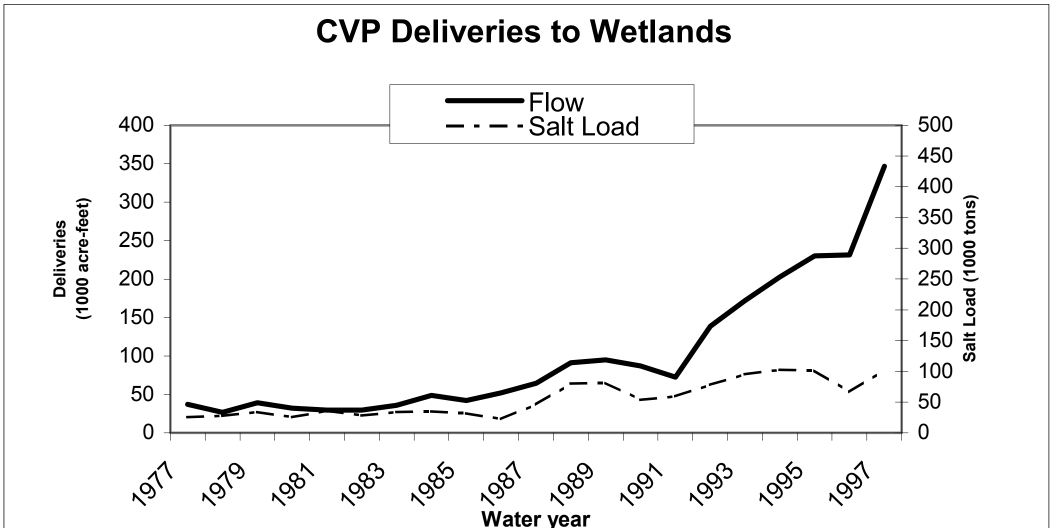
IV. Wetland Discharges:

There are approximately 160,000 acres of managed wetlands within the Grasslands Ecological Area (GEA). The GEA is the largest contiguous wetland complex remaining in the State of California and it is comprised of a combination of federal, sate and privately owned land within the TMDL project area. These wetlands are managed by the USFWS, the DFG, and by privately owned duck clubs, gun clubs, and water districts. Wetland acreage in the TMDL project area is anticipated to increase as more land is incorporated under state and federal refuge status. These wetlands are primarily managed as seasonal freshwater ponds or as permanent marshes, which provide habitat for an abundance of migratory birds.

Most of the supply water used to support the wetlands comes from the Delta via DMC. Peak water demand for the wetlands is between mid September and early November, when the wetlands are flooded. Supplemental water is also applied to the wetlands after flooding to replenish seepage and evaporative losses. Water demands for the wetlands are lowest from mid January through April. During this period the seasonal wetlands are drained to encourage germination of grasses that are an important food source for waterfowl. Fresh water supplements are required during the spring and summer for the irrigation of wetland vegetation and for the maintenance of permanent wetlands. During the summer months, wetland acreage is managed as irrigated pasture, seasonal, and semi-permanent wetlands.

Based on data contained in USBR Central Valley Operations monthly *Reports of Operation* (1979-1997), wetland users received an average of approximately 100,000 thousand acre-feet of supply water per year from the CVP between 1977 and 1997. Approximately 56,000 tons of salt per year were delivered to wetlands in their supply water between 1977 and 1997. Water deliveries to the wetlands, however, have significantly increased since the implementation of the Central Valley Project Improvement Act (CVPIA), which was enacted, in part, to provide more reliable water supplies for the wetland refuges. Consequently, increases in salt contributions to the wetlands have also occurred as a result of the increased water supply (Figure 3-5). Deliveries to the wetlands for 1995 through 1997 averaged 269,000 acre-feet per year.

Figure 3-5: Central Valley Project Deliveries to Wetlands



Source: flow data from USBR Central Valley Operations Office Reports of Operation 9176-1997, EC data used to calculate loads was provided by USBR staff spreadsheets

Limited data is available on wetland discharge water quality over a broad area. Much of this provides only a snapshot of information over a small area and a short time period. Figure 3-5 also shows that wetland deliveries and hence, discharges have changed dramatically in recent years. Rather than summarize sparse data on wetland discharges, an estimate has been made of wetland discharge quantity and quality based on recent wetland supply information. This estimate considers evaporative and groundwater losses of water applied to wetlands as well as dilution effects of rainfall. The methods to estimate wetland discharge quantity and quality are presented in Table 3-4. A mean delivery of 269,000 acre-feet per year at a mean concentration of 317 mg/L is assumed. Other assumptions are stated in the table.

This analysis estimates a mean net discharge from wetlands of 193,000 acre-feet per year at a salinity of 380 mg/L with a net salt discharge of 101,000 tons. This accounts for approximately five percent of the mean annual discharge at Vernalis and nine percent of the LSJR's total annual salt load.. This should be considered a minimum estimate of salt loading to the LSJR from the managed wetlands, as this analysis does not account for salt leaching from wetland soils and/or wetland derived groundwater accretions to surface drainages. It also does not account for salt concentrations in wetlands supply water that are higher than CVP/DMC water quality. Wetland Water supply typically includes a mix of DMC water, groundwater, and tail water returns (Chilcott, 2000a).

Table 3-4: Wetland Flows and Loads

Variable	Value	Units	Variable Type	Assumptions and References
mean evaporative loss	19	inches	Input	mean annual September through April based on CIMIS ET0 and precipitation data for WY's 94, 95, & 96
mean rainfall	10	inches	Input	mean annual September through April based on CIMIS ET0 and precipitation data for WY's 94, 95, & 96
porosity	43%	percent	Input	pore space for silty clay of Central Valley porosity ranges from 35 to 52%, mean of 43% USGS,1991 (GW in the CV of CA, Summary Report p. A14)
depth to groundwater	18	inches	Input	DWR water table maps
groundwater seepage	8	inches	Calc	=porosity X depth to groundwater
pond depth	12	inches	Input	
total acreage	171,000	acres	Input	USFWS National Wetlands Inventory-- GIS data and Regional Board GIS analysis (Appendix B)
percent pond coverage	32%	percent	Input	CDFG and Ducks Unlimited California Central Valley wetlands and riparian GIS data-- Regional Board GIS analysis (Appendix B)
ponded acreage	54720	acres	Calc	= total acreage X percent ponded acreage
total deliveries	269,000	acre-feet	Input	average delivery WY 1995 through 1997
TDS supply water	317	(mg/L)	Input	average TDS of supply water WY 1977 through 1997
Conversion factor	0.0013595		Constant	Conversion of Acre-Ft x mg/L to tons
net salt in	115,929	tons	Calc	= total deliveries X TDS supply water X Conversion factor
supplemental rainfall	45,600	acre-feet	Calc	= mean rainfall X total acreage
total water in	314,600	acre-feet	Calc	= total deliveries + supplemental rainfall
evaporative losses	86,640	acre-feet	Calc	= mean evaporative loss X ponded acreage / 12 inches
net water in	227,960	acre-feet	Calc	= total water in X evaporative losses
groundwater losses	35,294	acre-feet	Calc	= groundwater seepage X ponded acreage / 12 inches
groundwater salt losses	15,211	acre-feet	Calc	= groundwater losses X TDS supply water X Conversion factor
net discharge	192,666	acre-feet	Calc	= net water in - groundwater losses
net salt discharge	100,718	tons	Calc	= net salt in - groundwater salt losses
net water quality	385	(mg/L)	Calc	= net salt discharge/ net discharge / Conversion factor

V. Surface Agricultural Discharges:

Irrigated agriculture is the largest land use in the LSJR Watershed. Surface agricultural return flows are comprised of irrigation water that is applied and then runs off the ends of agricultural fields and operational spills of unused irrigation supply water. Irrigation water return flows result when water runs off the ends of agricultural fields after more water is applied to irrigated acreage than percolates into soils. This is most likely to occur in areas that are irrigated using flood or furrow irrigation methods. With these methods, water must be applied over sufficiently long periods so that enough water percolates into soil to satisfy the crops water use requirements. This results in unused water at the lower end of the irrigated field. This "tailwater" must be reused on some lower field, recaptured and pumped uphill to be reused, or flow via manmade and natural channels to the LSJR. Operational spills consist of irrigation supply water that is spilled directly from irrigation supply conveyances into manmade and natural channels.

The quantity and quality of surface agricultural return flows is dependent on the quantity and quality of irrigation supply water, the delivery and application method, and the extent to which the applied water has already been reused through tailwater recovery methods. There are three sources of irrigation supply water in the LSJR Watershed: surface water deliveries from in or out of the basin; groundwater pumping; and SJR diversions. The DMC and SWP provide the surface water component to the Grassland Watershed, Northwest Side, and the SJR upstream of Salt Slough Sub-areas. Deliveries from Millerton Lake via the Madera Canal also provide some of the surface water deliveries to the SJR upstream of Salt Slough Sub-area Major reservoirs on the major east side tributaries to the LSJR provide the surface water deliveries in the Merced River, Tuolumne River, Stanislaus River, and East Valley Floor Sub-areas.

Limited direct data is available to make a complete accounting of agricultural return flows in the LSJR Watershed. Information on irrigation supply water quantity and quality are, however, more readily available. Supply water delivery volume and quality can be used in conjunction with cropping patterns, weather, and other data to calculate agricultural return flow volumes and quality in the LSJR. These calculations are made in the San Joaquin River Input-Output (SJRIO) model that was developed to provide a quantitative accounting of flows, salinity, boron, and selenium in the LSJR for the SWRCB Order No. 85-1 Technical Committee Report to assess the impacts of agricultural drainage on SJR water quality (SWRCB, 1987). A full description of this mass balance water quality model is provided in Appendix C of this report (Kratzer et al, 1987). Model calculated surface agricultural return flows have been verified by comparison with measured agricultural return flows (Rashmawi et al, 1989). SJRIO model estimates show that surface agricultural return flows to the main stem SJR from the Northwest Side, Merced River, Tuolumne River, Stanislaus River, and East Valley Floor Sub-areas accounted for an average of 250,000 acre-feet of water and 150,000 tons of salt per year from 1985 through 1995. Additional model estimates show that the Grassland Watershed contributes an additional 60,000 acre-feet and 130,000 tons of salt annually. Total surface agricultural discharges to the LSJR are approximately 310,000 acre-feet and 280,000 tons of salt. Surface agricultural discharges therefore account for approximately eight percent of the mean annual discharge at Vernalis and 26 percent of the mean annual salt load.

V. Subsurface Agricultural Discharges:

Much of the irrigated acreage in the LSJR Watershed has poorly drained soils and shallow groundwater. Agricultural productivity may be adversely impacted if drainage is not provided to these areas, thereby keeping water out of the crop root zone. Productivity can be maintained if shallow groundwater is lowered below the depth of the root zone. Shallow groundwater is typically collected using a network of subsurface drains, (sometimes referred to as “tile drains” since the earliest drains were made of clay tile) installed at an appropriate depth and spacing. Water from these drains typically is collected in the subsurface in a series of lateral collector drains and is eventually pumped to the surface using sump pumps. The drainage can then flow by gravity to manmade and natural channels to the SJR. In some areas subsurface drainage may also be collected suing a series of deep ditches that intercept the shallow water table. This water can also be pumped and discharged to the SJR. Finally, in areas with high permeability soils, shallow groundwater can also be pumped to the surface directly without the use of subsurface collector drains.

Subsurface agricultural drainage quantity and quality is dependent on the quantity and quality of irrigation water, the native groundwater, and the characteristics of the irrigated soils. Additional salts and minerals will be leached from irrigated soils with a high salt and mineral content than soils with less native salts.

Subsurface agricultural drainage from a 97,000-acre area known as the Drainage Project Area (DPA) in the Grassland Watershed Sub-area, accounts for most of the subsurface drainage volume and salt load. Subsurface drainage from the DPA historically discharged to the SJR via a series of manmade and natural channels and Mud and Salt Sloughs. Subsequent to initiation of the Grassland Bypass Project in 1997, all the subsurface drainage is collected and discharged to the northern 28 miles of the San Luis Drain which discharges to Mud Slough eight miles upstream of the SJR confluence.

The volume of discharge from the DPA has ranged from 25,000 to 75,000 acre-feet per year from water year 1986 to 2000. The annual salt load has ranged from 110,000 to 240,000 tons per year and boron load from 430 to 940 pounds per year over this period. Improved irrigation and drainage management practices have been employed subsequent to development of the GBP in 1997. The mean annual discharge from water year 1997 to 2000 was 37,000 acre-feet. The mean annual salt and boron loads from 1997 to 2000 were 160,000 tons and 730 pounds respectively. The mean annual salt and boron concentrations were 3,200 mg/L and 7.2 mg/L, respectively. This represents only one percent of the mean annual discharge and 15 percent of the mean annual SJR salt load. Subsurface agricultural drainage from the DPA in the Grassland Sub-area represents the most concentrated source of salt and boron in the LSJR Watershed.

There is additional tile drained acreage outside of the DPA that drains directly to the LSJR. A 1985 survey of tile-drained areas identified approximately 10,000 acres that contribute subsurface agricultural drainage directly to the LSJR (SWRCB, 1987). Sampling and SJRIO model calculations indicate that these areas contribute approximately 11,000 acre-feet per year of subsurface drainage at a mean salinity of

1,700 mg/L. This accounts for mean annual salt loads of approximately 25,000 tons, accounting for approximately two percent of the mean annual salt load in the LSJR. This contribution of tile drainage from lands that discharge directly to the LSJR should be considered a minimum estimate because additional unsurveyed areas on the west and east side of the LSJR have been added since 1985.

3.6 Summary and Evaluation

Geographic Analysis
Table 3-5 summarizes the magnitude of salt and boron loads from each sub-area and the entire 2.9-million-acre LSJR watershed. On average, approximately 1.1 million tons of salt and 975 tons of boron were discharged each year from the LSJR at Vernalis. The Grassland and Northwest Side Sub-areas are the largest source of both salt and boron to the LSJR. Collectively these two sub-areas contribute approximately 67 percent of the LSJR's total salt load and 85percent of the LSJR's boron load. The Stanislaus, Tuolumne, and Merced River Sub-areas collectively contribute about 19 percent of the rivers total salt load and about nine percent of the LSJR's boron load. The East Valley Floor Sub-area provides approximately six percent of the LSJR's salt load and only one percent of the boron load.

Table 3-5: Total Sub-area Salt and Boron Loading (WY 1977-1997)

Sub-area	Discharge		Salt load		Boron load	
	thousand acre-feet	Percent	thousand tons	Percent	tons	Percent
LSJR upstream of Salt Slough	862	23%	100	9%	66	7%
Grassland	212	6%	400	37%	490	50%
North West Side	230	6%	320	30%	340	35%
East Valley Floor	149	4%	57	5%	21	2%
Merced River	549	15%	48	4%	14	1%
Tuolumne River	994	27%	92	9%	25	3%
Stanislaus River	679	18%	60	6%	19	2%
Totals	3,675	100%	1,077	100%	975	100%

Source Categories
Table 3-6 summarizes the magnitude of flows and salt loads attributable to each source category. The Sierra Nevada tributaries provide most of the flow and groundwater, and agricultural discharges contribute most of the salt. Groundwater is the single largest source of salt load, contributing on average, approximately 30 percent of the annual salt load in the LSJR. This high salt load greatly limits the capacity of the LSJR to assimilate additional salt loads. Though, agricultural development in the basin has likely increased the mass of salt load accretions to the LSJR, explicit limits for groundwater salt loads are not considered explicitly in this TMDL. The next largest contributor of salt to the LSJR are agricultural surface discharges, contributing 26 percent of the annual salt load.,

followed by subsurface agricultural return flows contribute, which contribute, on average, 17 percent of the average total salt loads in the LSJR. Subsurface agricultural discharges also represent the most concentrated source of salt to the river. The DPA is he source of most of this salt load. Wetland discharges account for at least nine percent of the mean annual LSJR salt load; municipal and industrial discharges account for only two percent of the mean annual load. The sum of individual source categories does not sum to the average annual LSJR salt load because different methods were used to calculate the loads for individual source categories. The mean annual LSJR discharge and salt load is based on the water year 1977 to 1997 historical average for the SJR near Vernalis. The information presented here is meant to provide a guide to understanding the relative loading from the six source categories, not as an exact calculation of salt loads.

Table 3-6: Source Category Salt Loading (WY 1985 to 1995)

Source Category	Discharge		Salt Load		Salinity
	thousand acre-feet	Percent*	thousand tons	Percent*	(mg/L)
Sierra Nevada Tributaries and LSJR Upstream of Salt Slough (background)	3100	84%	222	20%	52
Groundwater Accretions	148	4%	320	30%	1,600
Municipal and Industrial	28	1%	26	2%	680
Wetland	193	5%	101	9%	380
Agricultural Surface Return Flows	310	8%	280	26%	660
Agricultural Subsurface Return Flows (Grassland Watershed)	37	1%	164	15%	3,300
Agricultural Subsurface Return Flows (NWS)	11	0.3%	25	2%	1,700
Total (San Joaquin River near Vernalis)*	3,675	104%	1,077	106%	

* The total discharge and salt load for the San Joaquin River at Vernalis is based on the historical data for 1977 through 1997; the sum of source categories is different from total at Vernalis because independent methods were used to estimate source category discharge and salt loads (not a mass balance calculation)

Anthropogenic Salt and Boron Loads (Controllable Loads)

Inspection of the total mass loading from each sub-area allows for a macro-scale evaluation of the salt and boron sources on a geographic basis, however, TMDLs must focus control efforts on anthropogenic pollutant sources. Some of the salt and boron delivered to the LSJR from the sub-areas is simply "passed" through the sub-area from upstream or background sources. This is especially significant for the three eastside tributary sub-areas that receive a large volume of drainage from Sierra Nevada Runoff, and for the Northwest Side Sub-area that receives inflows from the Coast Range. The LSJR upstream of Salt Slough also receives significant inflows from upstream areas and Friant Dam releases, primarily during high flow events.

Background loads were estimated in order to ascertain the anthropogenic component of point and non-point sources within each of the Sub-areas. Appendix D shows the methods used to estimate background loads. The background and anthropogenic Sub-area salt loads are shown in Table 3-7. Background salt sources make up approximately 23 percent of the total estimated LSJR salt loads and 11 percent of the total boron loads. The Grassland and Northwest Side Sub-areas remain the largest sources of salt, contributing a combined total of 65.7 percent of the LSJR's anthropogenic or controllable salt load. However, approximately 69 percent or 486,603 tons of salt from these two sub-areas can be traced back to the Delta (see Salt Imports Section 3.5-III above). In fact over half of the LSJR's total annual anthropogenic salt load is being imported from the Delta, emphasizing that source water quality must be addressed to ensure that this TMDL results in the achievement of the numeric targets.

Table 3-7: Mean Annual Background and Anthropogenic/Controllable Salt and Boron Loads

Sub-area	Total load	Background load	Anthropogenic Load†	Percent of total load††
Salt Loading (thousand tons/year)				
LSJR upstream of Salt Slough	100	78	22	2.0%
Grassland	400	N/A	400	37.1%
North West Side	320	14	306	28.4%
East Valley Floor	57	8	49	4.5%
Merced River	48	34	14	1.3%
Tuolumne River	92	62	30	2.8%
Stanislaus River	60	46	14	1.3%
totals	1077	242	835	77.5%
Boron Loading (tons/year)				
LSJR upstream of Salt Slough	66	48	18	2%
Grassland	490	N/A	490	50%
North West Side	340	11	329	34%
East Valley Floor	21	2	19	2%
Merced River	14	11	3	<1%
Tuolumne River	25	20	5	1%
Stanislaus River	19	14	5	1%
totals	975	106	869	89%

† Anthropogenic load equals total load minus background load, the anthropogenic load is considered to be the controllable load. Anthropogenic loads include loads from agriculture, managed wetlands, groundwater and municipal sources.
†† Sub-area anthropogenic load as a percent of the total LSJR basin mass emissions.

Non-point Source Salt and Boron Loads

Most of the controllable salt and boron loading to the LSJR watershed comes from non-point sources. Point sources contribute approximately 3 percent of the LSJRs total controllable salt load. Approximately 25,500 tons of salt per year are discharged directly into the river as treated wastewater effluent from the cities of Modesto and Turlock. Both of these wastewater discharges are located within the East Valley Floor Sub-area. Therefore, the total controllable non-point source load for East Valley Floor is approximately 23,500 (equal to the anthropogenic load minus the point source load). Since the East Valley Floor Sub-area is the only sub-area that contains point sources that discharge to surface waters, the non-point source load for all of the other sub-areas is assumed to be equal to the anthropogenic load (Table 3-8).

Table 3-8: Mean Annual Loading by Sub-area and Major Source Type 1977-1997

	Source Category				
	AG/NPS Load		**M&I Load**	Sub-area Totals	
Sub-area	Salt (1,000 tons)	Boron (tons)	Salt (1,000 tons)	Salt (1,000 tons)	Boron (tons)
LSJR upstream of Salt Slough	22	18	0	22	18
Grassland	400	490	0	400	490
North West Side	306	329	0	306	329
East Valley Floor	24	19	25	49	19
Merced River	14	3	0	14	3
Tuolumne River	30	5		30	5
Stanislaus River	14	5	0	14	5
Category Totals:	**810**	**869**	**25**	**835**	**869**
	810	+	25	= 835	

Agriculture and managed wetlands are considered to be the predominant land uses that contribute to non-point source salt and boron loading in the LSJR watershed. The 2.9-million-acre TMDL project area contains approximately 1.4 million acres of agriculture and 160,000 acres of managed wetlands (Figure 3-6).

The project area also contains 134,289 acres of urban area, however, the majority of the salt loads generated from urban land uses are accounted for in municipal and industrial discharges. The salt load discharged in urban stormwater runoff was estimated using average daily precipitation from 1990 through 1997. A runoff coefficient for urban areas within the project area was developed using a modified version of the rational equation (Equation 3-2), precipitation data for Modesto, and stormwater discharge monitoring data from the McHenry storm drain (also in Modesto) for a single storm event in January of 2001.

$$Q=CIA \tag{3-2}$$

Where:
Q = peak runoff (cubic feet/second)
C =the runoff coefficient (dimensionless)
I = average rainfall intensity (feet/second)
A= drainage area (cubic feet)

The rational equation was rewritten (Equation 3-3) to solve for C (the runoff coefficient) and modified by using total runoff (Q) from the January 2001 storm event instead of peak runoff and total rainfall (I) from the same storm event instead of the average rainfall intensity.

$$C = \frac{Q_i}{I_i A} \qquad (3\text{-}3)$$

<u>Where:</u>
C = runoff coefficient for Modesto (dimensionless)
Q_i = total runoff from event i (cubic feet)
I_i = total rainfall from event i (feet)
A = catchment area (square feet)

The runoff coefficient provides an estimate of the relative amount of runoff generated from a given rain event. The drainage area of the McHenry storm drain is 1.33 square miles (37.1 million square feet) (USGS, 1998), the total runoff from the January 2001 storm event was calculated to be approximately 553,000 cubic feet, and the total rainfall volume from the same storm event was 0.535 inches (0.045 feet). The runoff coefficient for Modesto is therefore calculated to be 0.33, which indicates that the volume of runoff generated from the January 2001 storm event was equal to approximately 33 percent of the total rainfall volume. The 0.33 runoff coefficient agrees with published runoff coefficients values for single-family residential areas (Fetter, 1994). The urban runoff coefficient was used in conjunction with average daily precipitation data from California Irrigation Management Information System (CIMIS) stations in Modesto, Los Banos, and Kesterson to estimate daily runoff from the 134,289 acres of urban area contained in the project area. Average TDS concentrations for the rising (41 mg/L) and falling (25 mg/L) limbs of the January 2001 storm hydrograph were obtained from City of Modesto staff (Remsing, personal communication, 2001) and these values were applied to the estimated storm flows to calculate daily salt loads from urban runoff. No lag times for rainfall to runoff were considered. Based on this analysis, less than 2,500 tons of salt per year was discharged from urban stormwater runoff between water-years 1991 and 1997. This accounts for less than one quarter of one percent of the LSJR's total Salt load as measured at the Airport Way Bridge near Vernalis.

Unit-area Salt and Boron Loading (Yields)

A unit-area load or yield is defined as the mass of a particular constituent transported by a stream, divided by the drainage area of the watershed (USGS, 1997c). The non-point source unit-area salt and boron loads for the LSJR sub-areas were calculated by dividing the mean annual non-point source salt and boron loading (Table 3-9) by the area of "non-point source land uses". Agriculture and managed wetlands are considered the primary non-point source land uses in this TMDL. Assessing the per acre salt and boron yields from each sub-area, rather than the total load from each sub-area, helps to identify the areas causing the greatest relative impacts to the LSJR. Areas identified with high unit-area loading could be the areas with the greatest potential for unit-area load reductions. Additionally, evaluation of unit-area pollutant loads combined with the consideration of source water quality provides a means for the equitable allocation of available loads among the different sub-areas. With this approach, sub-areas load allocations will generally be proportional to the amount of agriculture and managed wetlands (non-point source land uses) within a given sub-area. This concept is described in more detail in section 4, Load Allocations and Waste Load Allocations.

Table 3-9: Non-point Source Land Uses/Non-point Source Salt and Boron Yields

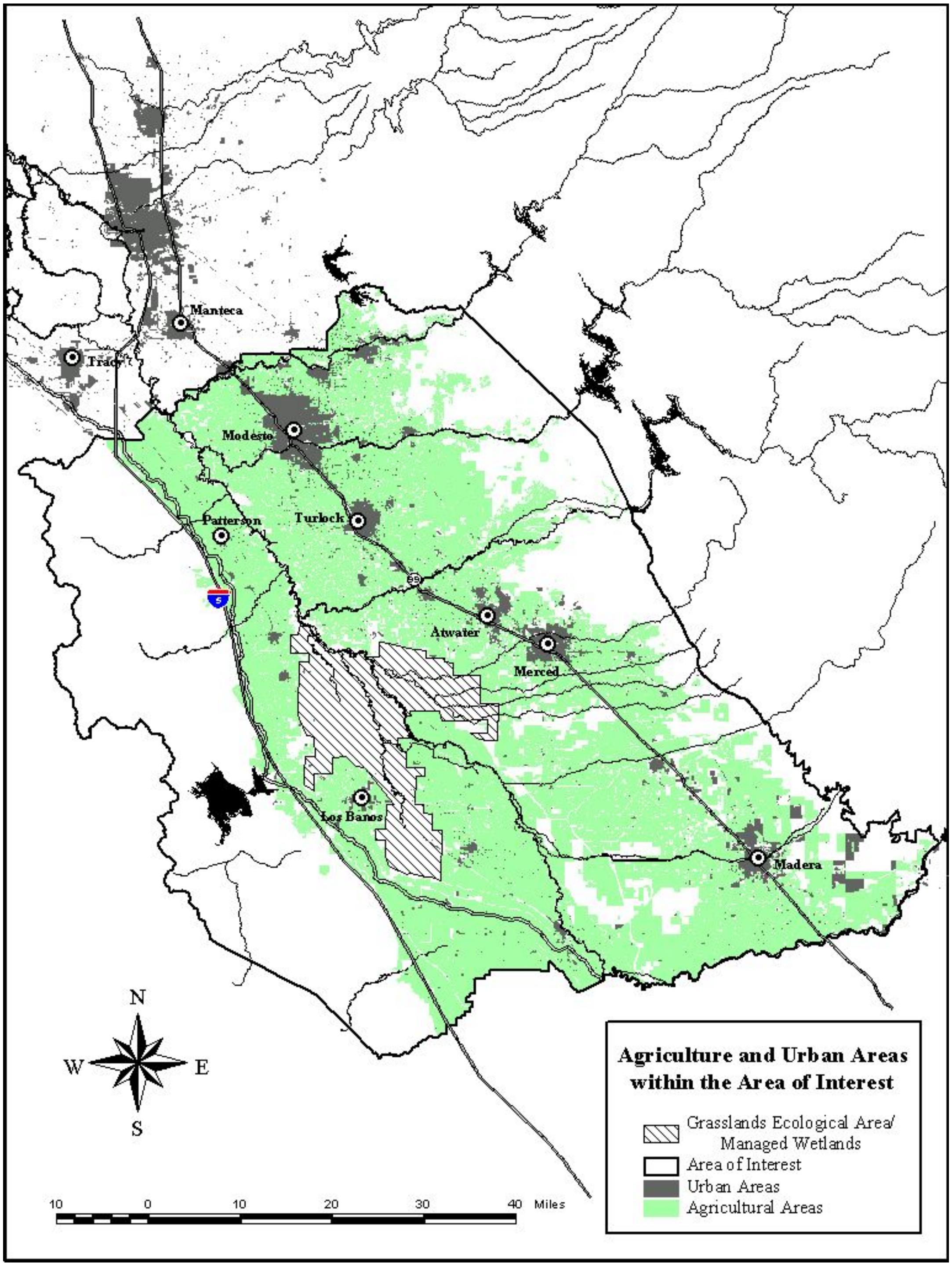
Sub-area	Acres in Agriculture	Acres in Wetlands	Total NPS acreage	Salt yield†† (tons/acre/year)	Boron yield†† (lbs./acre/year
LSJR upstream of Salt Sl. †	148,865	34,394	183,259	0.12	0.20
Grassland	330,858	99,864	430,722	0.93	2.28
North West Side	118,649	--	118,649	2.58	5.55
East Valley Floor	216,131	--	216,131	0.11	0.18
Merced River	94,180	--	94,180	0.15	0.06
Tuolumne River	52,111	--	52,111	0.58	0.19
Stanislaus River	52,715	--	52,715	0.27	0.19

†Acreages based on "effective drainage area" of SJR above Salt Sl.
††Salt and boron yields are the total NPS acres divided by the NPS loads in Table 3-8

Evaluation of the unit-area of salt and boron loading reveals that the Northwest Side Sub-area has the highest salt and boron yields of all the sub-areas, with non-point source salt and boron yields of approximately 2.6 tons per acre/year and 5.6 pounds per acre/year respectively. The yields given in Table 3-9, however, include salt and boron contributions from groundwater sources. Overlying land uses and management practices may influence salt and boron loading to the LSJR from shallow groundwater, however, these factors likely have little influence over deep groundwater from the Coast Range. The Northwest side is the sub-area most impacted by deep/regional groundwater salt and boron contributions from the Coast Range. Using an average estimated groundwater accretion of 1.26 cfs per mile, a TDS concentration of 2,000 mg/L, and a boron concentration of 1.3 mg/L, approximately 124,000 tons of salt per year are discharged from the deep coast range groundwater to the 50-mile reach of the LSJR river between the Mud Slough confluence and the Airport Way Bridge near Vernalis (river reach adjacent to the Northwest Side Sub-area). Subtracting the deep groundwater salt and boron loading contributions from the total NPS load for the Northwest Side results in a revised average non-point source salt load for the Northwest Side of 182,000 tons of salt per year and a non-point source salt yield of 1.5 tons per acre/year. When accounting for deep Coast Range groundwater, the total non-point source boron loading for the Northwest Side is decreased to 249 tons per acre/year and the boron yield is reduced to 4.2 pounds per acre/year. The Northwest Side Sub-area still has greatest salt and born yields even after subtracting out deep Coast Range groundwater contributions.

The Grassland Sub-area contributes the largest total NPS salt and boron loads to the river, however, the NPS source salt and boron yields are considerably lower than those of the Northwest Side. The LSJR upstream of Salt Slough Sub-area has the most agricultural lands and the lowest salt and boron yields of all the sub-areas. The Tuolumne River Sub-area is somewhat anomalous as its salt yield is more than twice that of the Stanislaus Sub-area and almost 4 times as high as the Merced River Sub-area. The average salt and boron yields from all of the Non-point source land use acreage in the entire TMDL project area are approximately 0.7 tons per acre/year and 1.5 pounds per acre/year respectively.

Figure 3-6: Lower San Joaquin River Major Non-point Source Land Uses†



† *Agriculture and urban land use classes extracted from DWR Land use data*

4.0 LOAD ALLOCATIONS AND WASTE LOAD ALLOCATIONS

4.1 Purpose and Overview

TMDL load allocations and waste load allocations set the pollutant load limits that, once achieved, will result in the attainment of the TMDL Numeric Targets. The TMDL load allocations and waste load allocations set forth in this report are intended to equitably apportion the available salt and boron loads among the sources identified in the TMDL Source Analysis. This TMDL establishes two sets of Load Allocations: 1) Pre-defined fixed numeric base load allocations based on design flows, and 2) formulaic real-time load allocations based on real-time river conditions. Both types of allocations are designed to meet the water quality objectives under virtually all conditions. This bi-model method of developing load allocations recognizes the need to maximize salt exports from the basin while meeting water quality objectives. Failure to export salt from the LSJR basin will likely result in a net salt buildup in the watershed and long-term degradation of ground and surface waters and a loss of agricultural productivity. Therefore, the pre-defined fixed load allocations presented below must be used in concert with the real-time load allocations to effectively implement this TMDL.

4.2 Methodology

The amount of a specific pollutant that a water body can receive and still maintain a water quality standard must be calculated in a TMDL. This loading capacity or TMDL is the full assimilative capacity of the water body. The loading capacity for the TMDL is found by multiplying a water quality objective (WQO) by the available flow, Q:

$$TMDL = Q * WQO \tag{4-1}$$

This loading capacity or TMDL must also be equal to the sum of the waste load allocations from point sources (WLA), the load allocations from non-point Sources (LA), background loads (BG), and an appropriate margin of safety (MOS). In this case the sum of the loads from groundwater loading (GW), have also been incorporated into the TMDL because significant loading from groundwater occurs in the LSJR watershed. The LSJR salt and boron TMDL can be described by Equation 4-2.

$$TMDL = WLA + LA + BG + GW + MOS \tag{4-2}$$

In a successful TMDL, the actual sum of loads from all point and non-point sources, background loads, groundwater loads, and margin of safety must be less than or equal to the TMDL. Calculation of the waste load allocations and load allocations must, in fact, be constrained by the calculated loading capacity (TMDL), the existing background loads and the margin of safety. It is therefore appropriate to reorganize the above equation to indicate the dependency of the waste load allocations and load allocations on the other factors:

$$WLA + LA = TMDL - (BG + GW + MOS) \tag{4-3}$$

This representation of typical TMDL components infers the sequential nature of calculating the waste load allocations and load allocations within the TMDL. This equation also shows that much information must be considered prior to making estimates of the waste load allocations and load allocations. Background loads, groundwater loads, a margin of safety, and other factors must be considered before loads are allocated to point and non-point sources. Additionally, the averaging period for the TMDL, data sources, and seasonal variations and critical conditions must all be considered prior to calculating the TMDL.

Finally, given the scope of this TMDL, with both point and non-point sources of salt and boron, a phased approach must be used for development of TMDL waste load allocations and load allocations

Phased Approach
A phased approach is required when a TMDL involves both point and non-point sources and the point source waste load allocation is based on a load allocation for which non-point source controls need to be implemented. This approach is also preferable because it allows for revision of waste load allocations and load allocations in response to changing hydrologic conditions and availability of additional data. As shown in the source analysis, point sources account for a very small percent of the total salt and boron load in the LSJR at the Airport Way Bridge near Vernalis.

The load allocation scheme proposed is based on a flat per acre allocation of salt and boron loads to non-point sources in the entire TMDL project area. An additional allocation is made for point source discharges. Refinements to this flat load allocation will likely be required based on the economic analyses required as part of the TMDL implementation and Basin Plan Amendment process.

Averaging Period
The numeric target for this TMDL is the 30-day running average EC for the SJR near Vernalis. Running average loads are difficult to define and more difficult to calculate because much of the available data and modeling tools for estimating design flows are only available for a monthly time step. Analysis of historical data shows that the statistics of the mean monthly EC are roughly equivalent to the statistics of the 30-day running average EC (Table 4-1). Furthermore, a monthly load limit is established, rather than a daily limit, because most agricultural water districts lack the facilities needed to manage drainage on a daily basis. Flows and loads in this TMDL are therefore evaluated on a monthly time step to calculate the total maximum *monthly* load (TMML). Rewriting Equation 4-1 for a monthly time step we obtain:

$$\text{TMML (tons)} = Q_{DF} * \text{WQO} * \text{(conversion factor)} \tag{4-4}$$

Where Q_{DF} is the monthly design flow or expected low flow condition. The conversion factor used to calculate mass loading in units of tons per month from discharge in acre-feet and the water quality objective (WQO) in mg/L is 0.0013595.

Additionally a site specific conversion factor must be used to convert EC (µs/cm) to TDS (mg/L); a general conversion factor of 0.61 can be used in-lieu of site specific data.

Following Equation 4-3 the monthly waste load allocations and load allocations are obtained using:

$$WLA + LA = TMML - BG - GW - MOS \qquad (4\text{-}5)$$

Table 4-1: Comparison Of 30-Day Running Average And Monthly Mean EC Violation Rates

Time Frame	**Violation Rate (WYs 86-98)**	
	Apr - Aug	**Sept - Mar**
30-day running average	49%	11%
Monthly mean	49%	11%

Data Sources

Determination of the appropriate flows to use for calculating the TMDL is challenging due to the significant variability in hydrology of the San Joaquin River. Application of design flows to calculate load allocations requires use of a hydrology that is similar to the present and future hydrology. Extensive historical flow data is available for the San Joaquin River near Vernalis, however, the use of the historical flow data is not always the best method to determine design flows because of the numerous structural and operational changes that have affected LSJR hydrology over time. The New Exchequer Dam on the Merced River was completed in 1969, Don Pedro Dam on the Tuolumne River was completed in 1971, and New Melones Dam on the Stanislaus River was completed in 1979. These dams significantly altered the annual and seasonal flow patterns of the LSJR. More recently, major operational changes caused by the Central Valley Project Improvement Act (CVPIA) and the Vernalis Adaptive Management Program (VAMP) have also changed the LSJR's hydrology.

In order to consider changes that have altered hydrologic patterns, design flows for this TMDL are based on results of the Department of Water Resources DWRSIM model output for DWR Study 771, instead of using historical data. DWRSIM is a planning and operations model that is used to assess water availability to the SWP under various scenarios (UCD, 1999). DWRSIM operates on monthly time-step and models flow in the SWP, the CVP, and the Delta over a 73-year period of record for WYs 1922 through 1994. DWRSIM is essentially a linked node model, and as such data can be accessed at any node in the modeled system. This enables the end-user to obtain river flow, diversion, and return flow data for different locations and operations. For example VAMP pulse flows are modeled discretely in DWRSIM.

DWRSIM and its component models can be used to calculate historic flow in the San Joaquin River under various levels of development. DWRSIM operates by first calculating unimpaired runoff or the flow that would have occurred under native (prewater development) conditions for the entire 73-year period of record. Once unimpaired runoff is calculated the model superimposes the desired level of development (structural and operational) on the historic unimpaired flows. The model therefore predicts the historic flows as if the system was operated historically the same way it is operated under current conditions. DWRSIM output includes river flows, diversions, and return flows at various control points (nodes) within the system and model output for a number of DWR studies, including CALFED Study 771, is publicly available via the internet (DWR, 2001). Flow data output from DWR's DWRSIM CALFED Study 771 used in this analysis is presented in Appendix F.

Model output from DWRSIM CALFED Study 771 was used for establishing design flows in this TMDL because it best represents current conditions by simulating flows with the existing infrastructure and operational policies in place. Accordingly, CALFED Study 771 includes water releases that are currently being made by the USBR, primarily from the New Melones Reservoir, to meet water quality objectives at Vernalis. These releases were prescribed by the SWRCB's Decision 1641 to ensure that the Vernalis EC objectives are achieved, however, the design flows are intended to represent expected flow conditions independent of water quality conditions. Development of design flows based, in part, on the releases made for water quality would be inherently flawed since the water quality releases would in effect create additional assimilative capacity at Vernalis that only exists as result of mitigation and not as a result of ambient flow. Consequently, the water quality releases were removed from the total flow at Vernalis for the purpose of establishing the design flows used in this TMML.

Seasonal Variations and Flow Regimes

The TMML model develops flow regimes by categorizing flow data (from DWRSIM output, Appendix F) based on water year type and month. Water year type is based on the SJR Index of unimpaired flows (DWR, 2000). This water year classification scheme identifies water years as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), or Wet (W). The SJR Index is composed of the unimpaired runoff from the four major rivers in the Basin:

Stanislaus River inflow into Melones Reservoir
Tuolumne River inflow into Don Pedro Reservoir
Merced River inflow into Exchequer Reservoir
San Joaquin River inflow into Millerton Reservoir

The index is determined as follows:

60% current year April through July runoff
20% current year October through March runoff
20% of the previous year index, not exceeding 0.9 million acre-ft

$$\text{SJR Index} = 0.6\,(\text{Apr to Jul runoff}) + 0.2\,(\text{Oct to Mar runoff}) + 0.2\,(\text{previous year SJR Index}) \quad (4\text{-}6)$$

Water year classifications are based on threshold values of the SJR Index:

Year Type	Thresholds (million acre-feet)
Wet	Equal to or greater than 3.8
Above Normal	Greater than 3.1 and less than 3.8
Below Normal	Equal to or less than 3.1 and greater than 2.5
Critical	Equal to or less than 2.5 and greater than 2.1
Dry	Equal to or less than 2.1

The five water year- types combined with twelve months result in 60 month/water-year type groupings.

The next step of the TMML is to sort the historic flow record from DWRSIM into the 60 month/water-year type groups. The lowest flow on record within each month/water-year type group was selected for the design flow. This process generated a set of sixty design flows to correspond to each combination of the 5 water-year types and 12 months. Table 4-2 provides descriptive statistics for the range of flows contained in each of the month/water-year type groupings; the entire record of sorted monthly flows is given in Appendix F.

Table 4-2: Design Flows At Vernalis And Descriptive Statistics For Month/Water-Year Type Groupings With VAMP Pulse Flows (TAF)

Year Type	Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	Mean	477	715	827	686	704	579	222	117	167	297	188	273
	Median	394	548	686	540	536	451	130	104	128	300	125	130
	Stdev	385	515	600	368	399	446	206	32	83	82	177	339
Design flow⇒	**Low Val**	**101**	**178**	**255**	**283**	**310**	**148**	**99**	**93**	**106**	**195**	**102**	**91**
	CV†	0.81	0.72	0.72	0.54	0.57	0.77	0.93	0.27	0.50	0.28	0.94	1.24
	10-pctile	128	225	331	380	355	186	105	94	117	215	108	106
Abv Norm	Mean	334	390	361	364	331	139	97	94	115	162	111	152
	Median	234	386	356	359	345	139	98	95	115	139	109	141
	Stdev	307	152	152	31	38	35	9	11	6	46	17	64
Design flow⇒	**Low Val**	**106**	**178**	**164**	**286**	**258**	**89**	**76**	**73**	**105**	**124**	**87**	**85**
	CV†	0.92	0.39	0.42	0.09	0.11	0.25	0.09	0.12	0.05	0.28	0.15	0.42
	10-pctile	107	211	180	344	284	110	88	83	109	125	93	101
Blw Norm	Mean	134	174	186	261	234	97	79	81	104	107	103	140
	Median	100	146	190	258	238	101	82	80	104	107	93	95
	Stdev	84	89	47	34	26	18	10	10	4	8	37	141
Design flow⇒	**Low Val**	**68**	**70**	**106**	**213**	**186**	**73**	**63**	**60**	**94**	**95**	**85**	**81**
	CV†	0.63	0.51	0.25	0.13	0.11	0.18	0.12	0.12	0.04	0.08	0.36	1.01
	10-pctile	71	86	140	222	207	77	67	71	100	100	86	83
Dry	Mean	117	145	139	199	176	56	48	57	81	98	91	158
	Median	116	135	120	212	190	58	48	57	83	96	93	103
	Stdev	23	48	44	51	30	9	11	6	5	10	11	168
Design flow⇒	**Low Val**	**79**	**99**	**95**	**149**	**141**	**39**	**34**	**44**	**71**	**78**	**73**	**77**
	CV†	0.19	0.33	0.32	0.25	0.17	0.16	0.22	0.10	0.06	0.10	0.12	1.06
	10-pctile	97	99	101	149	142	44	34	53	73	88	81	78
Critical	Mean	78	89	98	120	108	38	44	51	72	90	81	87
	Median	76	87	97	118	97	35	46	50	72	84	79	76
	Stdev	11	23	20	25	27	8	10	7	7	25	14	30
Design flow⇒	**Low Val**	**61**	**56**	**71**	**84**	**72**	**30**	**27**	**38**	**60**	**76**	**70**	**69**
	CV†	0.15	0.26	0.20	0.21	0.25	0.21	0.24	0.13	0.09	0.28	0.17	0.35
	10-pctile	68	65	75	92	78	30	31	44	64	78	71	70

†CV = Coefficient of Variance — All Flows are in Thousand Acre-feet (TAF)

Calculating the TMDL

Using Equation 4-4 the assimilative capacity of the LSJR can be calculated for each of the 60 month/water-year type groupings (Table 4-3). However, the total assimilative capacity of the river is not entirely available for allocation to the identified sources. The total assimilative capacity, or TMML, must be distributed between a waste load allocation (WLA) for point sources, a load allocation (LA) for non-point sources, a margin of safety (MOS), background loading (BG), and groundwater loading (GW).

Table 4-3: Total Assimilative Capacity For Salt (thousand tons)

Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	84	148	211	164	180	86	57	54	88	162	85	75
Abv. Normal	88	148	136	166	150	52	44	42	87	103	72	70
Blw. Normal	56	58	88	124	108	42	37	35	78	79	70	67
Dry	66	82	79	86	82	23	20	26	59	65	61	64
Critically Dry	51	46	59	49	42	17	16	22	50	63	58	57

Margin of Safety

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. The margin of safety can either be incorporated into conservative assumptions used to develop the TMDL or added as a separate component of the TMDL (U.S. EPA, 1991). No consistent errors have been identified in the flow and water quality information used to generate this TMML. This TMML incorporates an implicit margin of safety by using the lowest modeled flow on record as a design flow for each of the 60 month and water-year type combinations evaluated. Consequently, the fixed load allocations developed in this TMML are conservative and are designed to meet the Numeric Targets and water quality objectives under the most critical low flow conditions expected. Therefore, no explicit margin of safety is needed.

Groundwater Loads

According to Equation 4-2, salt loads attributable to groundwater accretions must be removed from the total assimilative capacity of the LSJR to determine the loads that are available to be allocated among point and non-point sources of pollution. Mean annual groundwater flows (GW_Q) to the LSJR were estimated to be 2 cfs per mile with a TDS concentration (GW_C) of 1,590 mg/L (see Source Analysis Sec. 3.5) (USGS, 1991). Applying the two cfs per mile accretion to 60 miles of the LSJR, 28 miles of Salt Slough, and 12 miles of Mud Slough (100 river miles total) yields a net accretion of 200 cfs or approximately 145,000 acre-feet per year. The seasonality of ground water accretions to the LSJR was estimated by using modeled monthly groundwater data available for 1979, 1981, 1982, and 1984-1985 (Figure 4-1) (SWRCB, 1987). The seasonal pattern of this modeled data was used to estimate a scaling factor; this is the percent of total annual groundwater accretion discharged per month. Monthly flows, Q_{GW}, and monthly loads, L_{GW}, were calculated from the annual discharge, $Q_{GW\ annual}$, using this scaling factor, SF, as shown in equation 4-7.

$$Q_{GW} = SF * Q_{GW\ annual} \quad ; \quad L_{GW} = SF * Q_{GW\ annual} * C_{GW} * \text{conversion factor} \quad (4\text{-}7)$$

Groundwater salt concentrations, C_{GW}, were held constant at 1,590 mg/L for each month and no adjustment for water-year type variability was made. Table 4-4 shows the calculated groundwater flows and associated salt loads for each of the 60 month/water-year type groupings.

Figure 4-1: Groundwater Seasonality and Scaling Factors

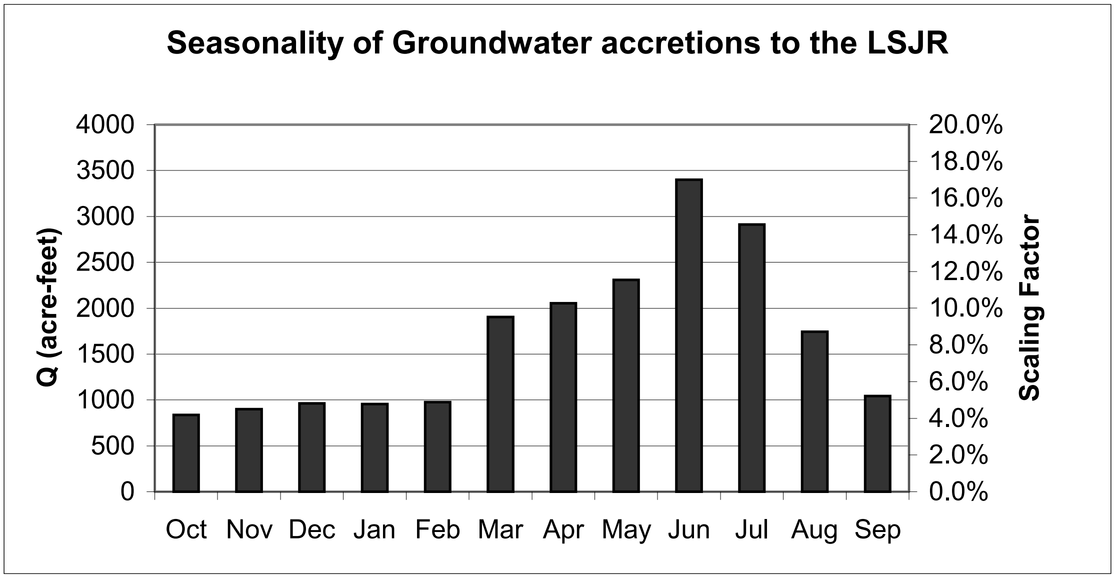


Table 4-4: Monthly Groundwater Flow and Salt Loads

Month	Mean Annual Flow (taf)	Scaling Factor	Monthly Flow (taf)	Monthly Load (1000 tons)
	$Q_{GW\ annual}$	SF	Q_{GW}	L_{GW}
Jan	145	4.78%	6.9	15
Feb	145	4.88%	7.1	15
Mar	145	9.52%	13.8	30
Apr	145	10.27%	14.9	32
May	145	11.54%	16.7	36
Jun	145	17.01%	24.7	53
Jul	145	14.57%	21.1	46
Aug	145	8.72%	12.6	27
Sep	145	5.21%	7.6	16
Oct	145	4.19%	6.1	13
Nov	145	4.49%	6.5	14
Dec	145	4.81%	7.0	15
Sum		100%	145	312

Groundwater accretions remain constant for all year types

Background Loads

Background loads include the salt and boron loads attributable to natural sources and inflows to the TMDL project area. For the purpose of this TMDL, background salt concentrations (C_{BG}) were set equal to 52 mg/L, the typical high quality supply water (inflows) from the Sierra Nevada (Appendix D). Monthly estimated groundwater accretions (Q_{GW}) were subtracted from the monthly design flows (Q_{DF}) to calculate background flow (Q_{BG}) (Equation 4-8). The background salt concentration of 52 mg/L was applied to the surface water component of the design flows (Q_{BG}) to calculate the background salt load (L_{BG}) for each of the 60 month/water-year type groupings (Equation 4-9, Table 4-5). This methodology assumes that all surface water flows in the LSJR have a background salt concentration of 52 mg/L and any additional salt content above 52 mg/L is of anthropogenic origin.

$$Q_{BG}=(Q_{DF}-Q_{GW}) \tag{4-8}$$

$$L_{BG} = Q_{BG} * C_{BG} * \text{conversion factor} \tag{4-9}$$

Table 4-5: Background Salt Loads (thousand tons)

Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	6.6	12.1	17.0	19.0	20.7	8.7	5.5	5.7	7.0	13.3	6.8	5.9
Abv. Normal	7.0	12.1	10.6	19.2	17.0	4.6	3.9	4.3	6.9	8.3	5.7	5.5
Blw. Normal	4.3	4.5	6.5	14.0	11.9	3.4	2.9	3.3	6.1	6.3	5.6	5.2
Dry	5.1	6.5	5.7	9.5	8.8	1.0	0.9	2.2	4.5	5.1	4.7	4.9
Critically Dry	3.8	3.5	4.0	4.9	3.9	0.4	0.4	1.8	3.7	4.9	4.5	4.4

Consumptive Use Allowance

TMDLs establish load limits to ensure that total loading to water body does not exceed that water body's total assimilative capacity. Establishing fixed load limits for naturally occurring elements becomes problematic when high quality discharges that provide additional assimilative capacity are restricted by the TMDL allocations. This is remedied in this TMDL by the use of a consumptive use allowance (CUA) for any discharges in the basin with water quality less than or equal to a "trigger value". This trigger value is a regulator/stakeholder-defined value that is based upon the expected discharge water quality from a non-point source that receives an excellent quality (low salt) supply water. All discharges equal to or less than the trigger value will be allowed in addition to the base load allocations established below. Additionally, for discharges above the trigger value, the portion of the discharge equal to the trigger value will be allowed in addition to the base load allowance. In affect, discharges at or below the trigger value will be unrestricted (not subject to load allocations or waste load allocations).

The trigger value recognizes that salts in the supply water will evapoconcentrate as applied water is consumptively used. This trigger value assumes a supply TDS concentration of 52 mg/L and 73 percent seasonal application efficiency (SAE). The Department of Water Resources defines the SAE as the sum of the evapotranspiration of applied water (ETAW) plus cultural water requirements (such as for leaching salts below the crop root zone) divided by the total applied water (AW). It is assumed that the state average SAE will reach 73 percent by the year 2020 (DWR, 1998). Using these assumptions the salinity trigger value would be set at 193 mg/L (Equation 4-10).

$$TV = \frac{C_{BG}}{(1 - SAE)} \tag{4-10}$$

Where:
TV = trigger value
C_{BG} = 52 mg/L (background concentration/supply quality)
SAE = .73 (seasonal application efficiency)

Raising the trigger value reduces the incentive to reduce water quality degradation because all discharges with concentrations below the trigger value are allowed by design. Conversely, lowering the trigger value reduces the ability to discharge high quality water that will provide additional dilution flow. Selecting a trigger value at or just below the water quality objective provides no incentive to reduce non-point source loading from areas that receive high quality supply water. Selecting a trigger value at or near the supply water quality provides no incentive to continue the spill of high quality dilution flow. The trigger value used in this initial TMML will likely need to be revised when economics are considered as part of the Regional Board's Basin Planning process.

The consumptive use allowance (CUA) for non-point sources is calculated using Equation 4-11. Note that the background concentration (C_{BG}) of 52 mg/L must be subtracted from the trigger value concentration of 193 mg/L because the background loads are already accounted for in the TMML. The background loading for each of the month/water-year type groupings is presented in Table 4-5.

$$CUA = (Q_{DF} - Q_{GW}) * (\text{Trigger Value} - C_{BG}) * \text{conversion factor} \tag{4-11}$$

Table 4-6: Consumptive Use Allowance Allocations For Salt (1000 tons)

Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	18.0	32.9	46.2	51.4	56.2	23.7	14.9	15.4	18.9	36.2	18.3	16.1
Abv. Normal	19.0	32.9	28.7	52.0	46.2	12.4	10.5	11.5	18.7	22.6	15.4	14.9
Blw. Normal	11.7	12.2	17.6	38.0	32.4	9.3	8.0	9.0	16.6	17.0	15.1	14.2
Dry	13.8	17.7	15.5	25.8	23.8	2.8	2.4	6.0	12.2	13.8	12.8	13.4
Critically Dry	10.3	9.5	10.9	13.3	10.5	1.1	1.1	4.8	10.1	13.4	12.2	11.9

Equation 4-2 must now be updated to reflect the consumptive use allowance so that the additional consumptive use load allowance is accounted for in the TMML:

$$TMDL = WLA + LA + L_{BG} + CUA + L_{GW} + MOS \tag{4-12}$$

The actual consumptive use allowance load granted to a discharger will depend on flow. Any increases in the consumptive use allowance above the design condition, however, will result in water quality improvement because the trigger value is substantially lower than the water quality objective.

Summary
After accounting for the margin of safety, groundwater loads, background loads, and the consumptive use allowance, the remaining load may be assigned to point and non-point sources through waste load allocations and load allocations. These elements are tabulated in Table 4-8.

4.3 Salinity Waste Load Allocations

The source analysis showed that salt and boron loads from point sources represent a small fraction of the total loads in the TMDL project area. For this reason, initial load allocations for point sources in this phased TMDL are set at existing historical loads for all months and year types during which there is assimilative capacity. No allocation is provided during months and year types during which there is no assimilative capacity.

Point source discharges from M&I sources are discussed in Section 3-5-III and Appendix C of this report. For TMDL planning purposes only municipal sources that discharge directly to surface waters were evaluated. Wastewater treatment plants for the City of Turlock and the City of Modesto are the only direct discharges to surface water in the TMDL project area. On average, these point sources contribute approximately 25,500 tons of salt per year. Of the 25,500 tons/year of salt that directly enters the LSJR, 6,500 tons/year enters during the 5-month irrigation season (April-August), and 19,000 tons/year enters during the 7-month non-irrigation season (September-March). This equates to approximately 1,300 tons of salt per month during the irrigation season and 2,714 tons of salt per month during the non-irrigation season.

Salt and boron loading for point sources in the LSJR watershed is relatively small compared to the loading from non-point sources. In this first phase of the TMML, the historic monthly mean irrigation and non-irrigation salt loads are used as the waste load allocations (WLAs) for point sources (Table 4-7). These WLAs range from 1.8% of the total annual assimilative capacity of the LSJR during a wet year to 4.7% of the total annual assimilative capacity during a critically dry year. The WLAs for point sources will be revised during the basin planning process. Future WLAs will likely be based on a combination of supply water quality, projected population growth, and application of best available/feasible treatment technologies. Additional waste load allocations may also be available when there is additional real time assimilative capacity (see *Need for Salt Balance* in section 4.4).

Table 4-7: Monthly Waste Load Allocations for Point Sources (1,000 tons)

All year types	Jan	Feb	Mar	Apr*	May*	Jun**	Jul	Aug***	Sep	Oct	Nov	Dec
City of Modesto	2	2	2	0.6	0.6	0	0	0	2	2	2	2
City of Turlock	0.7	0.7	0.7	0.7	0.7	0	0	0	0.7	0.7	0.7	0.7
Totals	2.7	2.7	2.7	1.3	1.3	0	0	0	2.7	2.7	2.7	2.7

* No waste load allocation available during critical year types
**Total waste load allocation for June for wet year types is 600 tons
*** Total waste load allocation for August for wet year types is 1,300 tons

Table 4-8: Total Load Allocations

		A	B	C	D	E	F	G	=C-D-E-F-G
Month/ Time period	Year Type	Design Flow	WQO	TMML	Background Load	Consumptive Use Allowance	Groundwater Load	WLA	LA
		(TAF)	(µS/cm)	------ 1000 tons ------					
Jan	Wet	101	1,000	84	6.6	18.0	15	2.7	41.7
	Abv. Norm	106		88	7	19.0	15	2.7	44.3
	Blw. Norm	68		56	4.3	11.7	15	2.7	22.3
	Dry	79		66	5.1	13.8	15	2.7	29.4
	Critical	61		51	3.8	10.3	15	2.7	19.2
Feb	Wet	178	1,000	148	12.1	32.9	15	2.7	85.3
	Abv. Norm	178		148	12.1	32.9	15	2.7	85.3
	Blw. Norm	70		58	4.5	12.2	15	2.7	23.6
	Dry	99		82	6.5	17.7	15	2.7	40.1
	Critical	56		46	3.5	9.5	15	2.7	15.3
Mar	Wet	255	1,000	211	17	46.2	30	2.7	115.1
	Abv. Norm	164		136	10.6	28.7	30	2.7	64.0
	Blw. Norm	106		88	6.5	17.6	30	2.7	31.2
	Dry	95		79	5.7	15.5	30	2.7	25.1
	Critical	71		59	4	10.9	30	2.7	11.4
Apr	Wet	283	700	164	19.0	51.4	32	1.3	60.6
	Abv. Norm	286		166	19.2	52.0	32	1.3	61.5
	Blw. Norm	213		124	14.0	38.0	32	1.3	38.3
	Dry	149		86	9.5	25.8	32	1.3	17.9
	Critical	84		49	4.9	13.3	32	0	0.0
May	Wet	310	700	180	20.7	56.2	36	1.3	65.8
	Abv. Norm	258		150	17.0	46.2	36	1.3	49.2
	Blw. Norm	186		108	11.9	32.4	36	1.3	26.3
	Dry	141		82	8.8	23.8	36	1.3	12.0
	Critical	72		42	3.9	10.5	36	0	0.0
Jun	Wet	148	700	86	8.7	23.7	53	0.6	0.0
	Abv. Norm	89		52	4.6	12.4	53	0	0.0
	Blw. Norm	73		42	3.4	9.3	53	0	0.0
	Dry	39		23	1	2.8	53	0	0.0
	Critical	30		17	0.4	1.1	53	0	0.0
Jul	Wet	99	700	57	5.5	14.9	46	0	0.0
	Abv. Norm	76		44	3.9	10.5	46	0	0.0
	Blw. Norm	63		37	2.9	8.0	46	0	0.0
	Dry	34		20	0.9	2.4	46	0	0.0
	Critical	27		16	0.4	1.1	46	0	0.0
Aug	Wet	93	700	54	5.7	15.4	27	1.3	4.6
	Abv. Norm	73		42	4.3	11.5	27	0	0.0
	Blw. Norm	60		35	3.3	9.0	27	0	0.0
	Dry	44		26	2.2	6.0	27	0	0.0
	Critical	38		22	1.8	4.8	27	0	0.0
Sep	Wet	106	1,000	88	7	18.9	16	2.7	43.4
	Abv. Norm	105		87	6.9	18.7	16	2.7	42.7
	Blw. Norm	94		78	6.1	16.6	16	2.7	36.6
	Dry	71		59	4.5	12.2	16	2.7	23.6
	Critical	60		50	3.7	10.1	16	2.7	17.5
Oct	Wet	195	1,000	162	13.3	36.2	13	2.7	96.8
	Abv. Norm	124		103	8.3	22.6	13	2.7	56.4
	Blw. Norm	95		79	6.3	17.0	13	2.7	40.0
	Dry	78		65	5.1	13.8	13	2.7	30.4
	Critical	76		63	4.9	13.4	13	2.7	29.0
Nov	Wet	102	1,000	85	6.8	18.3	14	2.7	43.2
	Abv. Norm	87		72	5.7	15.4	14	2.7	34.2
	Blw. Norm	85		70	5.6	15.1	14	2.7	32.6
	Dry	73		61	4.7	12.8	14	2.7	26.8
	Critical	70		58	4.5	12.2	14	2.7	24.6
Dec	Wet	91	1,000	75	5.9	16.1	15	2.7	35.3
	Abv. Norm	85		70	5.5	14.9	15	2.7	31.9
	Blw. Norm	81		67	5.2	14.2	15	2.7	29.9
	Dry	77		64	4.9	13.4	15	2.7	28.0
	Critical	69		57	4.4	11.9	15	2.7	23.0

4.4 Salinity Load Allocations

After accounting for the background loads, the consumptive use load allowance, groundwater loads, and the waste loads allocations, the remaining load is assigned to the load allocations for the non-point sources. The TMML (assimilative capacity) and background loads vary according to month and water-year type. Additionally, the waste loads allocations vary according to season and the groundwater loads vary according to month. Therefore, it follows that the load allocations to non-point sources also vary by month and water-year type since they are dependent on the background loads, groundwater loads and the waste load allocations (Equation 4-13). Load allocations are higher during wet months and years due to higher assimilative capacity in the LSJR. This initial load allocation is displayed in Table 4-8 on a monthly basis.

$$LA = TMML - L_{BG} - CUA - L_{GW} - MOS - WLA \qquad (4\text{-}13)$$

Vernalis Adaptive Management Plan (VAMP) Pulse Flow Considerations

VAMP is an adaptive management strategy intended to implement provisions of the SWRCB's Water Rights Decision 1641, in part, by providing a 31-day pulse flow in the LSJR. The pulse flow is intended to facilitate out-migration of Salmon smolt. Though this pulse flow is expected to occur from mid-April to mid-May, it may occur any time in April and May. To account for the VAMP-pulse flows, the monthly flow regimes of April and May must be split into a high flow and low flow two-week period in each month. This split results in less assimilative capacity during the first two weeks of April than there is during the last two weeks of April. Similarly, there is more assimilative capacity during the first two weeks of May than there is during the last two weeks of May.

For the purpose of establishing the load allocations, April and May must be split into three discrete time periods to address the uneven distribution of flow and assimilative capacity that occurs as a result of the VAMP pulse flows; 1) the beginning of April (April 1-14); 2) the VAMP pulse Period (April 15 – May15); and the end of May (May 16-31). This is accomplished by subtracting the VAMP pulse flows from the DWRSIM modeled output for Vernalis (Table 4-9) and recalculating the design flows and the TMML without the effect of the VAMP pulse flows (Table 4-10). The design flows and resultant TMMLs are only affected during April and May when the pulse flows are scheduled to occur.

The TMML for the beginning of April is equal to the percent of April in the beginning of April time period (Table 4-11) multiplied by the TMML for April calculated without VAMP flows (Table 4-10). Similarly, the TMML for the end of May is equal to the percent of May in the end of May time period multiplied by the TMML for May calculated without VAMP pulse flows. April flows and loads prior to the VAMP pulse, and May flows and loads after the VAMP pulse, are shown in table 4-12. Finally, the TMML during the VAMP pulse flow period is equal the original total TMML for April and May (from Table 4-8) minus the beginning April and end May TMMLs. The sum of the design flows and TMMLs for April and May in table 4-12 are equal to the design flows and TMMLs for April and May in table 4-8; only the distribution of flows and loads has been changed to account for the VAMP pulse. Note that there are now 65 month/water year type groupings due to the creation of the VAMP pulse flow period. It is also important to note that the actual start date of the VAMP pulse period is not necessarily April 15; it may vary from year to year based on observation of Salmon smolt out-migration.

Table 4-9: Design Flows with VAMP Pulse Flows Removed (TAF)

Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	101	178	255	244	295	148	99	93	106	195	102	91
Abv. Normal	106	178	164	267	188	89	76	73	105	124	87	85
Blw. Normal	68	70	106	169	153	73	63	60	94	95	85	81
Dry	79	99	95	123	108	39	34	44	71	78	73	77
Critically Dry	61	56	71	82	72	30	27	38	60	76	70	69
Shaded areas not affected by VAMP pulse flows												

Table 4-10:Total Assimilative Capacity/TMML with VAMP Pulse Flows Removed (1,000 tons)

Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	84	148	211	142	171	86	57	54	88	162	85	75
Abv. Normal	88	148	136	155	109	52	44	42	87	103	72	70
Blw. Normal	56	58	88	98	89	42	37	35	78	79	70	67
Dry	66	82	79	71	63	23	20	26	59	65	61	64
Critically Dry	51	46	59	48	42	17	16	22	50	63	58	57
Shaded areas not affected by VAMP pulse flows												

Table 4-11: April and May Split for VAMP Integration

<table>
<tr><th colspan="2">APRIL</th><th colspan="2">MAY</th></tr>
<tr><td colspan="2">------------------30 days ------------------</td><td colspan="2">------------------31 days ------------------</td></tr>
<tr><td>Beginning of April Period</td><td colspan="2">VAMP Pulse Period</td><td>End of May Period</td></tr>
<tr><td>(Apr 1-14)</td><td colspan="2">(Apr 15-May 15)</td><td>(May 16-May 31)</td></tr>
<tr><td rowspan="3">------------14 days -----------</td><td colspan="2">------31 days ------</td><td rowspan="3">------------16 days -----------</td></tr>
<tr><td>April in VAMP</td><td>May in VAMP</td></tr>
<tr><td>---16 days ---</td><td>---15 days ---</td></tr>
<tr><td>Percent of April</td><td colspan="2">Percent of April</td><td>Percent of May</td></tr>
<tr><td>47%</td><td colspan="2">53%</td><td>52%</td></tr>
<tr><td></td><td colspan="2">Percent of May</td><td></td></tr>
<tr><td></td><td colspan="2">48%</td><td></td></tr>
</table>

Table 4-12: Total Load Allocations with VAMP pulse flow period

		A	B	C	D	E	F	G	=C-D-E-F-G
Month/ Time period	Year Type	**Design Flow**	**WQO**	**TMML**	**Background Load**	**Consumptive Use Allowance**	**Groundwater Load**	**WLA**	**LA**
		(TAF)	(µS/cm)	1000 tons					
	Wet	101		84	6.6	18.0	15	2.7	41.7
	Abv. Norm	106		88	7	19.0	15	2.7	44.3
Jan	Blw. Norm	68	1,000	56	4.3	11.7	15	2.7	22.3
	Dry	79		66	5.1	13.8	15	2.7	29.4
	Critical	61		51	3.8	10.3	15	2.7	19.2
	Wet	178		148	12.1	32.9	15	2.7	85.3
	Abv. Norm	178		148	12.1	32.9	15	2.7	85.3
Feb	Blw. Norm	70	1,000	58	4.5	12.2	15	2.7	23.6
	Dry	99		82	6.5	17.7	15	2.7	40.1
	Critical	56		46	3.5	9.5	15	2.7	15.3
	Wet	255		211	17	46.2	30	2.7	115.1
	Abv. Norm	164		136	10.6	28.7	30	2.7	64.0
Mar	Blw. Norm	106	1,000	88	6.5	17.6	30	2.7	31.2
	Dry	95		79	5.7	15.5	30	2.7	25.1
	Critical	71		59	4	10.9	30	2.7	11.4
	Wet	114		66	7.6	20.5	14.9	0.6	22.7
	Abv. Norm	125		72	8.3	22.6	14.9	0.6	26.0
Beg. of Apr *	Blw. Norm	79	700	46	5.1	13.8	14.9	0.6	11.3
	Dry	57		33	3.6	9.7	14.9	0.6	4.3
	Critical	38		22	2.2	6.0	14.9	0.0	0.0
	Wet	327		190	22.0	59.6	34.5	1.3	72.4
	Abv. Norm	322		187	21.7	58.7	34.5	1.3	71.0
VAMP Pulse Period**	Blw. Norm	241	700	140	15.9	43.2	34.5	1.3	45.1
	Dry	177		103	11.4	30.8	34.5	1.3	24.7
	Critical	81		46	4.5	12.4	34.5	0.0	0.0
	Wet	152		88	10.2	27.5	18.6	0.7	31.3
	Abv. Norm	97		56	6.2	16.9	18.6	0.7	13.8
End of May***	Blw. Norm	79	700	46	5.0	13.5	18.6	0.7	8.2
	Dry	56		33	3.3	9.0	18.6	0.7	0.9
	Critical	37		22	2.0	5.4	18.6	0.0	0.0
	Wet	148		86	8.7	23.7	53	0.6	0.0
	Abv. Norm	89		52	4.6	12.4	53	0.0	0.0
Jun	Blw. Norm	73	700	42	3.4	9.3	53	0.0	0.0
	Dry	39		23	1	2.8	53	0.0	0.0
	Critical	30		17	0.4	1.1	53	0.0	0.0
	Wet	99		57	5.5	14.9	46	0.0	0.0
	Abv. Norm	76		44	3.9	10.5	46	0.0	0.0
Jul	Blw. Norm	63	700	37	2.9	8.0	46	0.0	0.0
	Dry	34		20	0.9	2.4	46	0.0	0.0
	Critical	27		16	0.4	1.1	46	0.0	0.0
	Wet	93		54	5.7	15.4	27	1.3	4.6
	Abv. Norm	73		42	4.3	11.5	27	0.0	0.0
Aug	Blw. Norm	60	700	35	3.3	9.0	27	0.0	0.0
	Dry	44		26	2.2	6.0	27	0.0	0.0
	Critical	38		22	1.8	4.8	27	0.0	0.0
	Wet	106		88	7	18.9	16	2.7	43.4
	Abv. Norm	105		87	6.9	18.7	16	2.7	42.7
Sep	Blw. Norm	94	1,000	78	6.1	16.6	16	2.7	36.6
	Dry	71		59	4.5	12.2	16	2.7	23.6
	Critical	60		50	3.7	10.1	16	2.7	17.5
	Wet	195		162	13.3	36.2	13	2.7	96.8
	Abv. Norm	124		103	8.3	22.6	13	2.7	56.4
Oct	Blw. Norm	95	1,000	79	6.3	17.0	13	2.7	40.0
	Dry	78		65	5.1	13.8	13	2.7	30.4
	Critical	76		63	4.9	13.4	13	2.7	29.0
	Wet	102		85	6.8	18.3	14	2.7	43.2
	Abv. Norm	87		72	5.7	15.4	14	2.7	34.2
Nov	Blw. Norm	85	1,000	70	5.6	15.1	14	2.7	32.6
	Dry	73		61	4.7	12.8	14	2.7	26.8
	Critical	70		58	4.5	12.2	14	2.7	24.6
	Wet	91		75	5.9	16.1	15	2.7	35.3
	Abv. Norm	85		70	5.5	14.9	15	2.7	31.9
Dec	Blw. Norm	81	1,000	67	5.2	14.2	15	2.7	29.9
	Dry	77		64	4.9	13.4	15	2.7	28.0
	Critical	69		57	4.4	11.9	15	2.7	23.0

** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*

Load Allocation Distribution
An allocation scheme was developed to equitably apportion the total load allocation to all non-point sources within the seven geographic sub-areas identified in the Source Analysis. Load allocations to each of the seven geographic sub-areas are proportional to the quantity of non-point source land use within each sub-area. As discussed in the source analysis, non-point source land use is the sum of the agricultural lands and the managed wetlands within each sub-area (Table 4-13).

Table 4-13: Sub-area Non-point Source Land Use

Sub-area	Acres in Agriculture	Acres in Wetlands	Total NPS acreage	NPS acreage percent of total
SJR above Salt Slough *	148,865	34,394	183,259	16%
Grasslands	330,858	99,864	430,722	38%
North West Side	118,649	--	118,649	10%
East Valley Floor	216,131	--	216,131	19%
Merced River	94,180	--	94,180	8%
Tuolumne River	52,111	--	52,111	5%
Stanislaus River	52,715	--	52,715	5%
TOTAL	1,013,509	134,258	1,147,767	100%

* acreages based on "effective drainage area" of SJR above Salt Slough

The base load allocation per non-point source land use acre is calculated by dividing the total base load allocations given in Table 4-12 by 1,147,767, which is the total non-point source land use acreage given in Table 4-13. The base load allocation in pounds per acre is given in Table 4-14. The sub-area load allocations are calculated by multiplying the non-point source land use acreage in each sub-area (Table 4-13) by the per acre load allocations in Table 4-14. The sub-area load allocations for seven sub-areas are given in Table 4-15.

Table 4-14: Base Load Allocations for Salt in lbs per Acre

Year-type	Month / Period												
	Jan	Feb	Mar	Beg. Apr*	VAMP Pulse Period **	End. May***	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	73	149	201	40	126	55	0	0	8	76	169	75	62
Abv. Norm	77	149	111	45	124	24	0	0	0	74	98	60	56
Blw. Norm	39	41	54	20	79	14	0	0	0	64	70	57	52
Dry	51	70	44	8	43	2	0	0	0	41	53	47	49
Critical	33	27	20	0	0	0	0	0	0	31	51	43	40

** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*

Table 4-15: Sub-area Base Load Allocations (tons)

Year-type	Month / Period												
	Jan	Feb	Mar	Beg. Apr*	VAMP Pulse Period **	End. May***	Jun	Jul	Aug	Sep	Oct	Nov	Dec
San Joaquin River upstream of Salt Slough Sub-Area Base Load Allocations in Tons													
Wet	6,657	13,623	18,379	3,623	11,556	4,995	0	0	740	6,930	15,456	6,894	5,638
Abv. Norm	7,078	13,623	10,211	4,144	11,339	2,203	0	0	0	6,817	9,007	5,453	5,088
Blw. Norm	3,563	3,772	4,977	1,810	7,196	1,313	0	0	0	5,845	6,382	5,210	4,779
Dry	4,695	6,398	4,004	694	3,944	145	0	0	0	3,770	4,859	4,284	4,470
Critical	3,059	2,445	1,817	0	0	0	0	0	0	2,798	4,633	3,929	3,677
Grassland Sub-Area Base Load Allocations in Tons													
Wet	15,645	32,020	43,197	8,515	27,160	11,741	0	0	1,739	16,289	36,327	16,202	13,252
Abv. Norm	16,636	32,020	23,999	9,739	26,650	5,177	0	0	0	16,023	21,170	12,816	11,958
Blw. Norm	8,375	8,867	11,697	4,255	16,914	3,087	0	0	0	13,737	15,000	12,246	11,232
Dry	11,036	15,036	9,411	1,631	9,270	342	0	0	0	8,862	11,420	10,070	10,507
Critical	7,189	5,746	4,270	0	0	0	0	0	0	6,576	10,888	9,235	8,643
Northwest Side Sub-Area Base Load Allocations in Tons													
Wet	4,310	8,820	11,899	2,346	7,482	3,234	0	0	479	4,487	10,007	4,463	3,651
Abv. Norm	4,583	8,820	6,611	2,683	7,341	1,426	0	0	0	4,414	5,832	3,530	3,294
Blw. Norm	2,307	2,442	3,222	1,172	4,659	850	0	0	0	3,784	4,132	3,373	3,094
Dry	3,040	4,142	2,593	449	2,554	94	0	0	0	2,441	3,146	2,774	2,894
Critical	1,980	1,583	1,176	0	0	0	0	0	0	1,811	2,999	2,544	2,381
East Valley Floor Sub-Area Base Load Allocations in Tons													
Wet	7,851	16,067	21,676	4,273	13,629	5,891	0	0	873	8,173	18,229	8,130	6,650
Abv. Norm	8,348	16,067	12,043	4,887	13,373	2,598	0	0	0	8,040	10,623	6,431	6,000
Blw. Norm	4,202	4,449	5,870	2,135	8,487	1,549	0	0	0	6,893	7,527	6,145	5,636
Dry	5,538	7,545	4,723	819	4,652	171	0	0	0	4,447	5,730	5,053	5,272
Critical	3,608	2,883	2,143	0	0	0	0	0	0	3,300	5,463	4,634	4,337
Stanislaus River Sub-Area Base Load Allocations in Tons													
Wet	1,915	3,919	5,287	1,042	3,324	1,437	0	0	213	1,994	4,446	1,983	1,622
Abv. Norm	2,036	3,919	2,937	1,192	3,262	634	0	0	0	1,961	2,591	1,568	1,463
Blw. Norm	1,025	1,085	1,432	521	2,070	378	0	0	0	1,681	1,836	1,499	1,375
Dry	1,351	1,840	1,152	200	1,135	42	0	0	0	1,085	1,398	1,232	1,286
Critical	880	703	523	0	0	0	0	0	0	805	1,333	1,130	1,058
Merced River Sub-Area Base Load Allocations in Tons													
Wet	3,421	7,001	9,445	1,862	5,939	2,567	0	0	380	3,562	7,943	3,543	2,898
Abv. Norm	3,638	7,001	5,248	2,130	5,827	1,132	0	0	0	3,504	4,629	2,802	2,615
Blw. Norm	1,831	1,939	2,558	930	3,698	675	0	0	0	3,004	3,280	2,678	2,456
Dry	2,413	3,288	2,058	357	2,027	75	0	0	0	1,938	2,497	2,202	2,297
Critical	1,572	1,256	934	0	0	0	0	0	0	1,438	2,381	2,019	1,890
Tuolumne River Sub-Area Base Load Allocations in Tons													
Wet	1,893	3,874	5,226	1,030	3,286	1,420	0	0	210	1,971	4,395	1,960	1,603
Abv. Norm	2,013	3,874	2,904	1,178	3,224	626	0	0	0	1,939	2,561	1,550	1,447
Blw. Norm	1,013	1,073	1,415	515	2,046	373	0	0	0	1,662	1,815	1,482	1,359
Dry	1,335	1,819	1,139	197	1,122	41	0	0	0	1,072	1,382	1,218	1,271
Critical	870	695	517	0	0	0	0	0	0	796	1,317	1,117	1,046

** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*

As discussed above, the seven sub-areas are also allocated a consumptive use allowance equal to sub-area discharge ($Q_{Sub\text{-}area}$) multiplied by the trigger value TDS concentration and a conversion factor. Therefore, the load allocations for each of the seven sub-areas ($LA_{Sub\text{-}area}$) are comprised of a fixed base load allocation (Table 4-15), and a formulaic consumptive use allowance that is dependent on sub-area discharge (Equation 4-14).

$$LA_{Sub\text{-}area} = LA_{Base} + (Q_{Sub\text{-}area} * TV * \text{conversion Factor}) \qquad (4\text{-}14)$$

where LA_{Base} is the fixed base load allocation and TV is the trigger value for the consumptive use allowance.

Considerations
The geographic scope of the TMDL and the nature of the pollutants of concern warrant identification and discussion of two factors that must be considered in the development of load allocations:

- The Central Valley Project has had a large impact on flow and salt loading
- There is a need for a salt balance to maintain agricultural productivity and achieve long-term San Joaquin River water quality improvement.

Central Valley Project Impacts
A discussion of assimilative capacity and load allocations cannot proceed without restating the impact of out-of-basin water exports and salt imports from out-of-basin. As discussed in the problem statement and source analysis sections of this TMDL, there have been major modifications to the flow regime in the SJR Basin. Much of this modification is attributable to small and large-scale local water development projects that have changed the timing and magnitude of flows within a sub-area. Construction of dams to provide a water supply for local use have dramatically changed the seasonal distribution of water and have increased the consumptive use of water in the basin. Such small and large-scale water developments are relatively easy to consider in a TMDL analysis of water supply and water quality. The impacts may be local or perhaps even basin-wide but the cost and benefit of such water quality development projects may be readily assigned to a local area that has control of its local supplies and deliveries.

Problems arise however when considering the impact of large-scale, basin-wide water development projects that have changed the timing and magnitude of flows within the entire SJR Basin. Such is the case for the impact of the USBR’s CVP and the City of San Francisco’s Hetch Hetchy diversions on SJR water quality. The City of San Francisco’s out-of-basin diversion of water from Hetch Hetchy in the Tuolumne River Basin has decreased flows in the SJR. The USBR’s CVP has had two profound impacts on SJR water quality:

1) decreased SJR flows resulting from the diversion of SJR water at Friant Dam to agricultural areas outside of the SJR Basin

2) increased salt load imports to the basin associated with the replacement of SJR water with imports from the Sacramento and San Joaquin River Delta

Decreased Flows

Decreased flows can have a profound effect on water quality by reducing the ability of a waterbody to assimilate pollutant load and still comply with water quality objectives. The issue of decreased flows clearly has a water rights component. Therefore, this impact will not be addressed directly within this TMDL since this change in flow is a water rights issue and as such is beyond the authority of the Regional Board. Only the flow regime based on the current level of development and water rights framework are considered in the load allocation component of this TMDL.

Increased Salt Loads/Import Water Relaxation

The increased salt load impact of the CVP must be considered in this TMDL because of the significant potential adverse impact to dischargers in the Grassland Watershed and Northwest Side Sub-areas. The base load allocation is based upon an even distribution of assimilative capacity to non-point source discharges in all sub-areas. This even distribution fails to account for the dramatic differences in supply water quality to these areas. Without accounting for these differences in supply water, dischargers in some sub-areas will be unfairly limited in their ability to meet baseline load allocations.

The massive addition of salt load in imported irrigation supply water adversely impacts the ability of dischargers in these sub-areas to meet load allocations based on a flat per acre load allocation evenly allocated between sub-areas. To account for this constraint on the ability to meet a basin-wide aerial load allocation, dischargers that receive poor quality irrigation supply water will be given an additional base load import water relaxation. This “import water relaxation” is set at 50 percent of mean salt load imported to the sub-area during low flow conditions. The 50 percent salt return factor is based on the assumption that there will be a 30 percent return flow with some added salt to account for evapoconcentration and leaching of salt from prior years. No additional load allocation is provided for high salinity water derived from and used within a sub-area, such as from groundwater pumping.

Delta Mendota Canal Delivery Allocations

Salt imports from the DMC to the Grassland and Northwest side Sub-areas was calculated using output from the DWRSIM model over the same 73-year period of record used to develop the design flows and historical EC data. The DWRSIM model tracks agricultural diversions at various “control points” along the DMC. The DMC deliveries were divided into three source reaches. Reach 1 is from the Tracy pumping plant to just before the O’Neill Forebay, reach 2 is from just after the O’Neill Forebay to the Mendota Pool, and reach 3 represents deliveries made directly from the Mendota Pool. Table 4-16 summarizes the modeled flow data that was extracted from the DWRSIM output and used to develop the delivery design flows.

Table 4-16: DWRSIM Control Points Used To Determine DMC Delivery Design Flows

DWRSIM Control Point	Description	DMC Reach	Receiving Sub-area
CP-701	CVP UPPER DMC PROJECT AG DIV, ACTUAL DIVERSION	Reach 1	NWS
CP-721	CVP LOWER DMC PROJECT AG DIV, ACTUAL DIVERSION	Reach 2	Grassland
CP-722	CVP LWR DMC EXCHANGE (CCID) DIV, ACTUAL DIVERSION	Reach 2	Grassland
CP-723	CVP LOWER DMC VOLTA REFUGE DIV, ACTUAL DIVERSION	Reach 2	Grassland
CP-730	CVP MENDOTA POOL,PROJECT AG DIV, ACTUAL DIVERSION	Mendota Pool	Grassland
CP-731	CVP MENDOTA POOL, EXCHANGE DIV, ACTUAL DIVERSION	Mendota Pool	Grassland
CP732	CVP MENDOTA POOL, REFUGE DIV, ACTUAL DIVERSION	Mendota Pool	Grassland

Modeled water deliveries for control points 721,722, and 723 were added together to obtain the total flow delivered from the lower DMC (Reach 2) to the Grassland Sub-area. Similarly, the modeled deliveries for control points 730,732, and 733 were added together to obtain the total flow delivered from the Mendota pool (Reach 3) to the Grassland Sub-area. The total deliveries from the upper DMC to the Northwest Side Sub-area are represented by control point 701 (Reach 1).

Modeled deliveries to the Northwest Side and Grassland Sub-areas were sorted by month and water-year type. Deliveries to the lower DMC (Reach 2) and the Mendota pool (Reach 3) were kept separate to account for differences in the water quality diverted at the two locations. The minimum delivery for each of the month/water-year type groupings was selected as the delivery design flow for that month/water-year type grouping (Table 4-17). This method is consistent with the method used to develop the design flows for calculating the TMML. Historical mean monthly EC data for the DMC at Tracy from water years 1977 through 1997 was used to estimate the TDS of the supply water delivered from the Lower DMC (Reach 1). The 21-years of mean monthly EC data was sorted by month and water-year type and the mean value for each month/water-year type grouping was used as the average EC value. An EC to TDS conversion factor of 0.62 was used to convert mean monthly EC in µS/cm to mean monthly TDS in mg/L. The average of the EC values for dry and above normal years was used for below normal years because no below normal years occurred during the 21-year period of record.

Monthly mean EC data was also available for DMC at Check 13 and DMC at Check 21 for water-years 1993 through 1997. Check 13 was used to represent the water quality of deliveries made from the lower DMC (Reach 2) and Check 21 was used to represent the quality of deliveries made from the Mendota Pool (Reach 3). Linear regression analysis of the available data was used to develop correlations between the EC at Tracy and the EC at Checks 13 and 21 (Figure 4-2). These correlations were applied to the EC at Tracy to estimate the EC at check 13 and check 21. Generally, the mean salinity of diversions from the DMC increases during dryer years and decreases during wetter years. The apparent decrease in salinity between Tracy and check 13 is likely due to dilution effects from the combined operations of the SWP and CWP at the San Luis Reservoir fore bay. The apparent increase in salinity between check 13 and check 21 is likely due to evapoconcentration and saline discharges into the DMC. The TDS concentrations used to calculate the salt imports from the DMC to the Northwest side and Grassland Sub-area are presented in Table 4-18.

Table 4-17 DMC Delivery Design Flows (TAF)

NORTHWEST SIDE SUB-AREA													
Upper DMC Reach 1-Tracy	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
W	0	1	0	6	15	8	19	26	22	10	10	4	0
AN	0	0	0	5	12	7	16	21	19	8	8	3	0
BN	0	0	0	5	15	10	24	32	22	13	13	5	0
D	0	0	0	0	2	1	2	3	3	1	1	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0	0
GRASSLAND SUB-AREA													
Lower DMC Reach 2-Check 13	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
W	2	9	25	15	36	20	47	50	39	25	21	10	4
AN	2	9	19	14	32	18	42	45	42	23	19	10	4
BN	2	8	18	14	36	22	51	55	39	27	22	10	4
D	3	8	15	10	24	13	30	30	30	17	14	6	3
C	2	8	15	9	22	12	26	27	26	15	11	5	2
Mendota Pool Reach 3-Check 21	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
W	8	22	57	42	104	59	127	118	117	106	110	49	18
AN	9	21	46	39	95	54	117	108	106	100	105	47	18
BN	8	20	44	40	104	62	134	126	121	110	114	50	18
D	11	19	38	32	78	44	96	89	88	80	85	38	15
C	8	19	38	29	71	40	88	81	80	73	76	34	13

Figure 4-2: Check 13 and Check 21 EC Correlations with Tracy EC

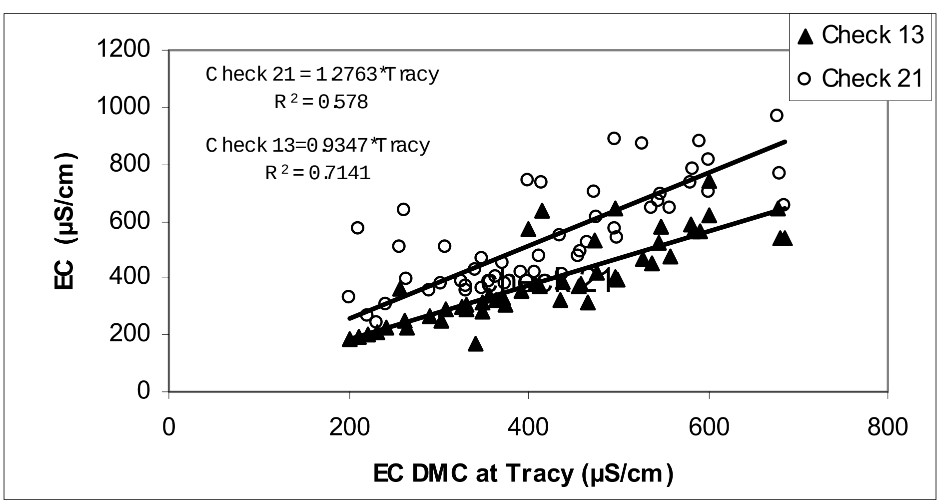


Table 4-18: Design Salt Concentrations For Deliveries From The DMC (mg/L)

NORTHWEST SIDE SUB-AREA													
Upper DMC Reach 1-Tracy	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	297	280	256	213	197	182	205	199	228	202	190	256	246
Abv. Normal	179	244	224	291	283	276	259	210	250	279	203	203	185
Blw. Normal	208	300	322	329	304	279	263	247	273	335	266	300	293
Dry	237	357	419	367	325	283	267	284	296	392	330	397	400
Critically Dry	445	459	450	372	364	356	402	416	413	420	435	458	508
GRASSLAND SUB-AREA													
Lower DMC Reach 2-Check 13	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	277	262	240	199	184	170	192	186	213	189	177	239	230
Abv. Normal	167	228	210	272	265	258	243	196	234	261	190	189	173
Blw. Normal	194	281	301	307	284	261	246	231	255	313	249	280	273
Dry	222	333	392	343	303	264	250	265	276	366	308	371	374
Critically Dry	416	429	420	348	340	332	376	389	386	393	407	428	475
Mendota Pool Reach 3-Check 21	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	379	358	327	272	252	232	262	254	290	258	242	327	315
Abv. Normal	228	311	286	371	362	352	331	268	320	356	259	259	236
Blw. Normal	265	383	411	419	388	356	336	315	349	428	340	383	373
Dry	302	455	535	468	414	361	341	362	377	500	421	507	511
Critically Dry	568	585	574	475	464	454	513	531	528	537	556	584	649

Salt load imported from the Delta via the DMC to the Northwest Side and the Grassland Sub-areas, L_{DMC}, is calculated using the delivery design flows, Q_{DMC}, in Table 4-17, the DMC delivery salt concentrations, C_{DMC}, in Table 4-18, and Equation 4-15. The background concentration of all water in the LSJR, C_{BG}, is assumed to be 52 mg/L, which is based on high quality inflows from the Sierra Nevada. The background concentration is subtracted from the DMC delivery concentration, in Equation 4-15 because the salt loads associated with background flows are not credited as part of the DMC delivery allocation/relaxation.

$$L_{DMC} = Q_{DMC} * (C_{DMC} - C_{BG}) * \text{conversion factor} \qquad (4\text{-}15)$$

Salt loads for the Lower DMC (Reach 2) and the Mendota Pool (Reach 3) are added to calculate the total salt load imported to the Grassland Sub-area. The salt load from the Upper DMC (Reach 1) is equivalent to the total salt load diverted from the DMC to the Northwest Side. A 50 percent salt return factor is applied to the salt imports to calculate the import water relaxation. In effect, the Northwest Side and the Grassland Sub-areas receive an additional “Import Water” load allocation, above and beyond the base load allocations, to compensate for their degraded supply water quality. This import water relaxation is equal to 50 percent of calculated imported salt load minus naturally occurring background salt (Table 4-19).

Table 4-19: DMC Import Water Relaxation Allocations For Salt (1000 tons)

NORTHWEST SIDE SUB-AREA													
	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	0.0	0.2	0.0	0.7	1.4	0.7	2.0	2.6	2.6	1.0	0.9	0.6	0.0
Abv. Normal	0.0	0.0	0.0	0.8	1.9	1.0	2.3	2.3	2.6	1.2	0.8	0.3	0.0
Blw. Normal	0.0	0.0	0.0	1.0	2.6	1.5	3.4	4.2	3.3	2.5	1.9	0.8	0.0
Dry	0.0	0.0	0.0	0.1	0.3	0.2	0.3	0.5	0.5	0.2	0.2	0.0	0.0
Critically Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRASSLAND SUB-AREA													
	Month/Period												
Year Type	Jan	Feb	Mar	Beg. Apr	VAMP Pulse Period	End May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	2.1	5.9	13.9	7.8	17.3	8.8	22.6	20.8	23.2	17.2	16.0	10.4	3.7
Abv. Normal	1.2	4.8	9.4	10.4	24.7	13.6	27.6	20.3	24.5	23.9	16.6	7.5	2.6
Blw. Normal	1.4	5.7	13.8	12.5	29.5	15.9	32.6	29.2	29.8	32.9	25.3	12.8	4.5
Dry	2.2	6.7	15.9	11.1	23.4	11.2	22.9	23.1	24.0	28.0	23.7	13.0	5.3
Critically Dry	3.3	8.9	17.2	10.2	24.1	13.3	33.3	32.5	31.8	27.5	28.7	13.6	5.9

Lower San Joaquin River Diversion Allocations

The Grassland Sub-area receives the majority of it's supply water directly from the DMC. However, a significant portion of the Northwest Side Sub-area's agricultural supply water is diverted directly from the LSJR. The agricultural supply water diverted out of the LSJR between the Merced River confluence and the Stanislaus River confluence is degraded from upstream sources. Drainage from Salt and Mud Sloughs contains salts imported from the DMC as well as salts generated from wetland and agricultural uses within the Grassland Sub-area.

Similar to the additional allocations granted for DMC deliveries, an additional load allocation is made to the Northwest Side to account for the degraded LSJR surface water supply. A concentration and a delivery flow are needed to calculate the salt load associated with the LSJR surface water diverted to the Northwest Side. DWRSIM model output from CALFED study 771 was used once again to determine the quantity of water diverted from the River. Consistent with all the other hydrologic modeling data used in this analysis, the critical low flow for each month and year type grouping was used as the design flow for LSJR diversions to the Northwest Side (Table 4-20).

Table 4-20: Northwest Side Sub-Area Diversions From The LSJR (TAF)

Year-type	Month / Period												
	Jan	Feb	Mar	Beg. Apr*	VAMP Pulse Period **	End. May***	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	0	1	8	6	16	11	24	25	23	13	3	0	0
Abv. Norm	0	1	7	6	15	10	23	24	22	13	2	0	0
Blw. Norm	0	1	9	7	19	13	27	29	26	15	3	0	0
Dry	0	1	8	6	17	11	25	26	24	14	3	0	0
Critical	0	1	7	5	14	9	20	21	19	11	3	0	0
** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*													

The LSJR diversions to the Northwest Side Sub-area are set at the water quality that would occur at the LSJR downstream of the Merced River confluence under design flow conditions with the TMDL in place (Equation 4-16, Table 4-21).

$$C_{LSJR\ Div} = \frac{LA_{LSJR\ abv\ SS} + LA_G + LA_{MR} + L_{GW} + L_{BG} + L_{CUA}}{Q_{DF\ MR}} \qquad (4\text{-}16)$$

Where:

$C_{LSJR\ Div}$ = concentration of LSJR diversions
$LA_{LSJR\ abv\ SS}$ = total monthly load allocation for the LSJR upstream Salt Slough Sub-area
LA_G = total monthly load allocation for the Grassland Sub-area‡
LA_{MR} = total monthly load allocation for the Merced River Sub-area
L_{GW} = monthly groundwater loading
L_{BG} = monthly background loading
L_{BG} = monthly consumptive use allowance
$Q_{DF\ MR}$ = design flow of LSJR downstream of the Merced River

‡ The Grassland Sub-area load allocation includes a base load allocation, a DMC import water relaxation and a consumptive use allowance. All other sub-area load allocations include a base load allocation and a consumptive use allowance.

Table 4-21: Northwest Side Sub-Area LSJR Diversion Salt Concentrations (mg/L)

Year-type	Month / Period												
	Jan	Feb	Mar	Beg. Apr*	VAMP Pulse Period **	End. May***	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	957	964	1,723	1,553	893	1,526	1,103	1,432	1,358	1,103	673	1,119	1,092
Abv. Norm	1,049	1,188	1,096	1,976	1,230	1,636	1,446	1,577	1,408	1,238	1,099	1,128	1,144
Blw. Norm	886	980	944	1,520	1,157	1,585	1,542	1,729	1,519	1,390	1,231	1,172	1,090
Dry	925	1,036	1,026	1,593	1,028	1,442	1,669	1,978	1,298	1,226	1,195	1,270	1,156
Critical	1,069	1,195	995	1,521	1,626	1,724	1,904	2,050	1,779	1,195	1,248	1,245	1,158
** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*													

Once the supply water quantity, $Q_{LSJR\ Div}$, and quality, $C_{LSJR\ Div}$, are determined, salt loading from LSJR diversions, $L_{LSJR\ Div}$, can be calculated using Equation 4-17. Note that the background concentration, C_{BG}, of 52 mg/L is subtracted from the diversion concentration because the background loads are not credited to the Northwest side as part of their LSJR diversion allocation. Consistent with the DMC import water relaxation, a 50 percent salt return factor is also applied to the total salt load diverted from the river to calculate the LSJR diversion allocation.

$$L_{LSJR\ Div} = Q_{LSJR\ Div} * (C_{LSJR\ Div} - C_{BG}) * \text{ conversion factor} \qquad (4\text{-}17)$$

The Northwest Side Sub-area's LSJR diversion allocation for each month/water-year type groupings is presented in Table 4-22.

Table 4-22: Northwest Side Sub-Area LSJR Diversion Allocation For Salt (1000 tons)

Year-type	Month / Period												
	Jan	Feb	Mar	Beg. Apr*	VAMP Pulse Period **	End. May***	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	0.0	0.6	9.1	6.2	9.3	10.9	17.1	23.4	20.4	9.3	1.3	0.0	0.0
Abv. Norm	0.0	0.8	5.0	7.3	12.2	11.1	21.8	24.9	20.3	10.5	1.4	0.0	0.0
Blw. Norm	0.0	0.6	5.5	7.0	14.3	13.4	27.3	33.1	25.9	13.6	2.4	0.0	0.0
Dry	0.0	0.7	5.3	6.4	11.1	10.7	27.5	34.0	20.3	11.2	2.3	0.0	0.0
Critical	0.0	0.8	4.5	5.1	14.8	10.6	25.2	28.5	22.3	8.5	2.4	0.0	0.0

** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*

<u>Central Valley Project Load Allocations</u>
The additional load allocation assigned to the Northwest Side and Grassland Sub-areas compensates for the local impact of degraded CVP and surface water supplies delivered/diverted to these sub-areas. This addition to the base load allocation will result in exceedance of the established targets because the base load allocations alone fully utilize the available assimilative capacity of the river. If no allowance is made for the load contributed to the Grassland Watershed and the Northwest Side by out of basin irrigation water imports, then dischargers in these sub-areas will be constrained in their ability to meet baseline load allocations. Alternately, if salt loads associated with imported irrigation water are considered as background loads in the TMDL there will be little or no assimilative capacity available for all sub-areas and the burden of these reduced load allocations will be born by sub-areas outside of the direct influence of the CVP.

Recognizing that the USBR's actions have reduced water quality of the SJR at Vernalis, the SWRCB in Water Right Decision 1641 amended the permits under which the USBR delivers water to the San Joaquin River Basin. The Order in this decision amended the CVP permits under which the USBR delivers water to the San Joaquin Basin to require that the USBR meet the 1995 Bay Delta Plan Salinity objectives at Vernalis, which are equivalent to the numeric targets established in this TMDL.

Consistent with the SWRCB's Water Rights Decision 1641, this TMDL recognizes that the USBR's actions have greatly contributed to water quality degradation in the LSJR. As discussed in the source analysis, almost half of the LSJR's total annual salt load is imported to the LSJR watershed via the CVP. Accordingly, responsibility is placed on the USBR for salt load in the CVP water delivered to the TMDL project area that is in excess of a base load for an equivalent volume of Sierra Nevada quality water. The USBR's load responsibility more than compensates for the additional allocations provided to sub-areas that receive CVP water because the DMC import water allocation and the LSJR diversion allocation are only equivalent to 50 percent of the imported load less background loads. This provides an additional implicit Margin of Safety in the TMDL analysis and ensures that the water quality objectives will be met.

The USBR's salt load allocation is equal to the volume of water delivered from the CVP at a background Sierra Nevada water quality of 52 mg/L TDS. The delivery design flows for the Upper DMC, the Lower DMC and the Mendota Pool (Table 4-14) are added to determine the total design flow for all DMC deliveries to the TMDL project area. The delivery design flows are multiplied by 52 mg/L and a conversion factor to calculate the USBR's allocation (Table 4-23). The USBR would be responsible for any salt load in CVP deliveries to the TMDL project area that are in excess of their allocation. The USBR's responsibility for excess loads could be reduced or eliminated by improving supply water quality or through mitigation anywhere in the LSJR basin.

Table 4-23: USBR Load Allocations For CVP Deliveries (1000 tons)

Year-type	Month / Period												
	Jan	Feb	Mar	Beg. Apr*	VAMP Pulse Period **	End. May***	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	0.7	2.3	5.8	4.5	10.9	6.2	13.6	13.7	12.6	10.0	10.0	4.5	1.6
Abv. Norm	0.8	2.1	4.6	4.1	9.9	5.6	12.4	12.3	11.8	9.3	9.3	4.2	1.6
Blw. Norm	0.7	2.0	4.4	4.2	11.0	6.6	14.8	15.1	12.9	10.6	10.5	4.6	1.6
Dry	1.0	1.9	3.7	3.0	7.3	4.1	9.0	8.6	8.6	6.9	7.1	3.1	1.3
Critical	0.7	1.9	3.7	2.7	6.5	3.7	8.1	7.6	7.5	6.2	6.2	2.8	1.1

** Beginning of April runs 4/1-4/14 ** VAMP runs from 4/15-5/15 ***End of May runs from 5/16-5/31*

Need for Salt Balance

TMDL development for salt and boron in the Lower San Joaquin River (LSJR) presents unique challenges because of the nature of the pollutants being addressed and because of the way water is managed in the basin. As described in the source analysis, salt and boron are naturally occurring elements that are distributed over a wide area. Land management and water delivery practices have increased salt and boron loading to the LSJR. Exacerbating the problem, LSJR discharges to the Sacramento-San Joaquin Delta are re-circulated to the basin when water is pumped from the Delta and delivered back to the upper reaches of the TMDL project area. The salts in supply water from the Delta and naturally occurring salts that are leached from the soil during irrigation must be exported from the basin or isolated in order to maintain a salt balance in the soils and groundwater.

Most TMDLs limit the mass of pollutant discharged from various sources within a watershed to facilitate attainment of water quality objectives. Some estimate of flow or volume in the receiving water body is required to determine its loading capacity and to determine the load limits that will result in attainment of the water quality objectives. The design flows and subsequent base load allocations established in this TMDL have been designed to account for the variable conditions associated with monthly and climatic (e.g. dry year, wet year) discharge patterns. To be conservative and minimize the number of water quality exceedances, these design flows are based on the critical low flow that is expected to occur during a given month/water-year type combination. The base load allocation represents an expected worst-case, minimum load allocation for which dischargers must have the ability to comply. However, most of the time the actual flow in the river will be greater than the design flow because the design flow is based on critical conditions. Under a strict interpretation of the TMDL guidance, use of the river's full assimilative capacity to maximize salt exports would not be permitted whenever actual flow exceeds the pre-determined design flow.

Limiting discharges through static load allocations may be necessary for pollutants that bioaccumulate or have a cumulative effect on receiving water quality, however, this approach is not appropriate for salt and boron in the LSJR because it does not recognize the need to export salt and the variations of assimilative capacity that occur within the predefined set of flow regimes (month/water-year types). Implementation of an overly restrictive TMDL based on static load allocations would require dischargers to retain more salt on site, resulting in a net build up of salts in the soil and groundwater. Once salts are diffused into the groundwater system they become harder to manage. Retained salts would eventually be discharged to the LSJR through uncontrolled groundwater accretions.

<u>Real-time allocations</u>

A real time load allocation process has been incorporated into this TMDL to facilitate more efficient salt management by reducing drainage and groundwater interactions and by allowing salts to be discharged during times when there is additional assimilative capacity. The real-time load allocations allow for a prescribed departure from the TMML base load allocations.

The real-time load allocations are based on real-time flow and water quality conditions and on a weekly or monthly forecast of assimilative capacity. The real-time load allocations would supercede the base allocations whenever the real-time load allocations are greater than the base load allocations. Since real-time flow and water quality conditions are not known ahead of time, the real-time load allocations must be formulaic. The real-time load allocations, LA_{RT}, for all non-point sources are calculated using the appropriate seasonal water quality objective, WQO, the forecasted real-time flow, Q_{RT}, and the forecasted real-time salt concentration, C_{RT}, in the LSJR. A 20 percent explicit margin of safety is incorporated into the real-time load allocation equation (Equation 4-18) to account for potential monitoring equipment or calculation error.

$$LA_{RT} = [(Q_{RT} * WQO) - (Q_{RT} * C_{RT})] * 0.8 \qquad (4\text{-}18)$$

Similar to the base load allocations, the real-time load allocations for non-point sources are evenly distributed between all non-point sources based on the size of the drainage area of the source. The real-time load allocation for a given sub-area is therefore proportional to the acres of non-point source land use within that sub-area. The real-time load allocations, LA_{RT}, are divided by 1,147,767 acres, which is the total non-point source land use acreage, to calculate the per acre real-time load allocation:

$$\text{Per acre } LA_{RT} = [(Q_{RT} * WQO) - (Q_{RT} * C_{RT})] * 0.8 / 1{,}147{,}767 \text{ acres} \qquad (4\text{-}19)$$

The per-acre real-time load allocation is multiplied by the amount of non-point source land use acreage in each sub-area (Table 4-11) to determine the individual sub-area real-time load allocations. Additional waste load allocations will also be available to point source dischargers.

Implementation of a real-time management program will require a coordinated effort among the discharges in the LSJR watershed. Point and nonpoint source dischargers will need to develop and maintain the necessary operational and facilities infrastructure to provide accurate forecasts of assimilative capacity and to manage discharges to coincide with real-time conditions. Development of a proven real-time management framework would be prerequisite to the utilization of the "additional real-time load". The base load allocations established above will remain in effect until an acceptable real-time management program is developed. Guidance for a real-time management framework will be included in the implementation plan for this TMDL.

4.5 Calculation of Load Allocations

Load allocations are based upon several factors, including acreage of the area contributing to the non-point source discharge, source of irrigation supply water, and discharge flow volume. It is not possible to provide a simple table of load allocations because of the dependence of load allocations on discharge flow volumes and supply water sources. The following is meant to provide examples of how the load allocation for specific time periods and specific areas is calculated.

Example 1: Calculation of the load allocation for the entire Grassland Sub-area in March of an above normal year when the total volume of discharge from non-point sources is 30,000 acre-feet.

The base load allocation in March of an above normal water year, for the Grassland Sub-area, as shown in Table 4-15, is 23,999 tons. The consumptive use allowance (CUA) for the 30,000 acre-feet of discharge adds an additional 7,874 tons:

CUA = Trigger value TDS * volume of discharge in acre-feet * conversion factor
CUA = 193 mg/L * 30,000 acre-feet * 0.0013599
CUA = 7,874 tons

Finally, the CVP supply water relaxation in March of an above normal water year, for the Grassland Sub-area, as shown in Table 4-19, provides an additional 9,400 tons of salt per year. The total load allocation for the Grassland Sub-area is therefore 41,273 tons:

Base Load Allocation	:	23,999
Consumptive Use Allowance	:	7,874
CVP Supply Water Relaxation	:	9,400
Total Load Allocation	**:**	**41,273**

This is the total load allocation for March in a year classified as above normal in the LSJR for discharges from the Grassland Sub-area. For reference, discharge from the Grassland Sub-area in March, 1999 (an above normal water year) was 35,000 acre-feet and 66,000 tons of salt (Crader et al., 2002, draft).

This load allocation does not consider real time conditions in the LSJR. Contingent upon development of the infrastructure to identify periods of assimilative capacity and manage the re-operation of discharges, an additional real time load allocation will be provided to the Grassland Sub-area. The Grassland Sub-area would receive 38 percent of any additional assimilative capacity, as calculated for the SJR near Vernalis (Table 4-13). This percentage is based on the percent of non-point source land use in the Grassland Sub-area relative to the total non-point source land use in the LSJR Basin.

Finally, the addition of the CVP supply water relaxation can have the effect of providing load allocation in excess of the assimilative capacity on the SJR. This excess load is mitigated by a load reduction by the USBR. In this example the USBR would be responsible for mitigating for a quantity of salt in delivery water to the LSJR Basin in excess of 4,400 tons (March of an above normal water year in Table 4-23). The actual load responsibility is based upon actual delivery volume and concentration but on average this responsibility will be approximately twice the supply water relaxation provided to the non-point source discharges. In this example the USBR responsibility would be approximately 27,600 tons for March of an above normal water year for delivery water supplied to the Grassland Sub-area. (twice the value shown for March in an above normal year in Table 4-19).

Example 2: Calculation of the load allocation for the entire Northwest Side Sub-area for September of a dry year when the total volume of discharge from non-point sources is 5,000 acre-feet.

The base load allocation in September of a dry water year, for the Northwest Side Sub-area, as shown in Table 4-15, is 2,441 tons. The consumptive use allowance (CUA) for the 5,000 acre-feet of discharge adds an additional 1,312 tons:

CUA = Trigger value TDS * volume of discharge in acre-feet * conversion factor
CUA = 193 mg/L * 15,000 acre-feet * 0.0013599
CUA = 1,312 tons

The Northwest Side Sub-area receives supply water from the CVP and from LSJR diversions. This sub-area, therefore, receives two supply water relaxations, one for the water delivered from the CVP and one for the water diverted from the LSJR. The CVP supply water relaxation in September of a dry water year, for the Northwest Side Sub-area, as shown in Table 4-19, provides an additional 200 tons of salt per year. The LSJR supply water relaxation for the same month and year-type provides an additional 9,200 tons of salt per year (Table 4-22). The total load allocation for the Northwest Side Sub-area is therefore 13,153 tons:

Base Load Allocation	:	2,441
Consumptive Use Allowance	:	1,312
CVP Supply Water Relaxation	:	200
LSJR Supply Water Relaxation	:	9,200
Total Load Allocation	**:**	**13,153**

This is the total load allocation for September in a year classified as dry in the LSJR for discharge from the Northwest Side Sub-area. This load allocation does not consider real time conditions in the LSJR. Contingent upon development of the infrastructure to identify periods of assimilative capacity and manage the re-operation of discharges, the Northwest Side Sub-area would receive ten percent of any additional assimilative capacity, as calculated for the SJR near Vernalis (Table 4-13). This percentage is based on the percent of non-point source land use in the Northwest Side Sub-area relative to the total non-point source land use in the LSJR Basin.

Addition of the supply water relaxation can have the effect of providing load allocations in excess of the assimilative capacity on the SJR. This excess load is mitigated by a load reduction by the USBR. In this example the USBR would be responsible for mitigating for a quantity of salt in delivery water to the LSJR Basin in excess of 6,900 tons (September of a dry water year in Table 4-23). The actual load responsibility is based upon actual delivery volume and concentration but on average this responsibility will be approximately twice the supply water relaxation provided to the non-point source discharges. In this example the USBR responsibility would be approximately 400 tons for September of a dry year for delivery water supplied to the Northwest Side Sub-area (twice the value shown for September in a dry year in Table 4-19).

4.6 Linkage Analysis

A linkage analysis is used to describe the relationship between the numeric targets, identified sources, and the total assimilative capacity (loading capacity) of the waterbody. In this TMDL the existing water quality objectives for salinity and boron are used as numeric targets, therefore, an analytical link between the numeric targets and protection of beneficial uses of the LSJR has already been established. The linkage analysis for this TMDL is intended to demonstrate that the waste load allocation and load allocations will result in attainment of the water quality objectives.

For this linkage analysis, output from the DWRSIM model (CAFFED Study 771) is used to calculate the modeled assimilative capacity of the LSJR at the Airport Way Bridge near Vernalis over the over the same 73-year period of record used to develop the design flows. The total expected load with the TMDL in place for the LSJR at the Airport Way Bridge near Vernalis is calculated by adding the TMDL waste loading allocations, load allocations, the estimated salt loading from groundwater, background loading, and consumptive use allowance loading (Appendix G). Figure 4-3 shows a comparison of modeled assimilative capacity and estimated monthly salt loading with the TMDL in place.

The total estimated salt load and the modeled flow from DWRSIM for the LSJR at the Airport Way Bridge near Vernalis are used to calculate a concentration. Monthly EC is compared to the seasonal water quality objective (Figure 4-4) and a violation of the water quality objective occurs whenever the calculated salt concentration exceeds the water quality objective. This is a check to see if the salinity water quality objective would have been met if proposed load allocations had been applied to DWRSIM modeled flow data for water-years 1922 to 1994. The linkage analysis for this TMDL resulted in 131 violations of the numeric target on a monthly basis. This approximately equates to a 15 percent violation rate, however, no waste load allocations or load allocations were available during any month when a violation occurred. These 131 violations resulted from groundwater loading, background loading, and consumptive use allowance loading only. No violations occurred during any month when waste load allocations or load allocations were available. Thus, the proposed TMDL achieves consistent compliance with the salinity objective for every month when salt discharges are allowed from agricultural and municipal sources. The remaining violations are due to groundwater, background and consumptive use loadings that are not considered to be controllable factors within the scope of this TMDL.

Figure 4-3: Comparison of linkage analysis assimilative capacity and the LSJR loading with TMDL in place from water year 1922 through water year 1994 for the SJR at the Airport Way Bridge Near Vernalis.

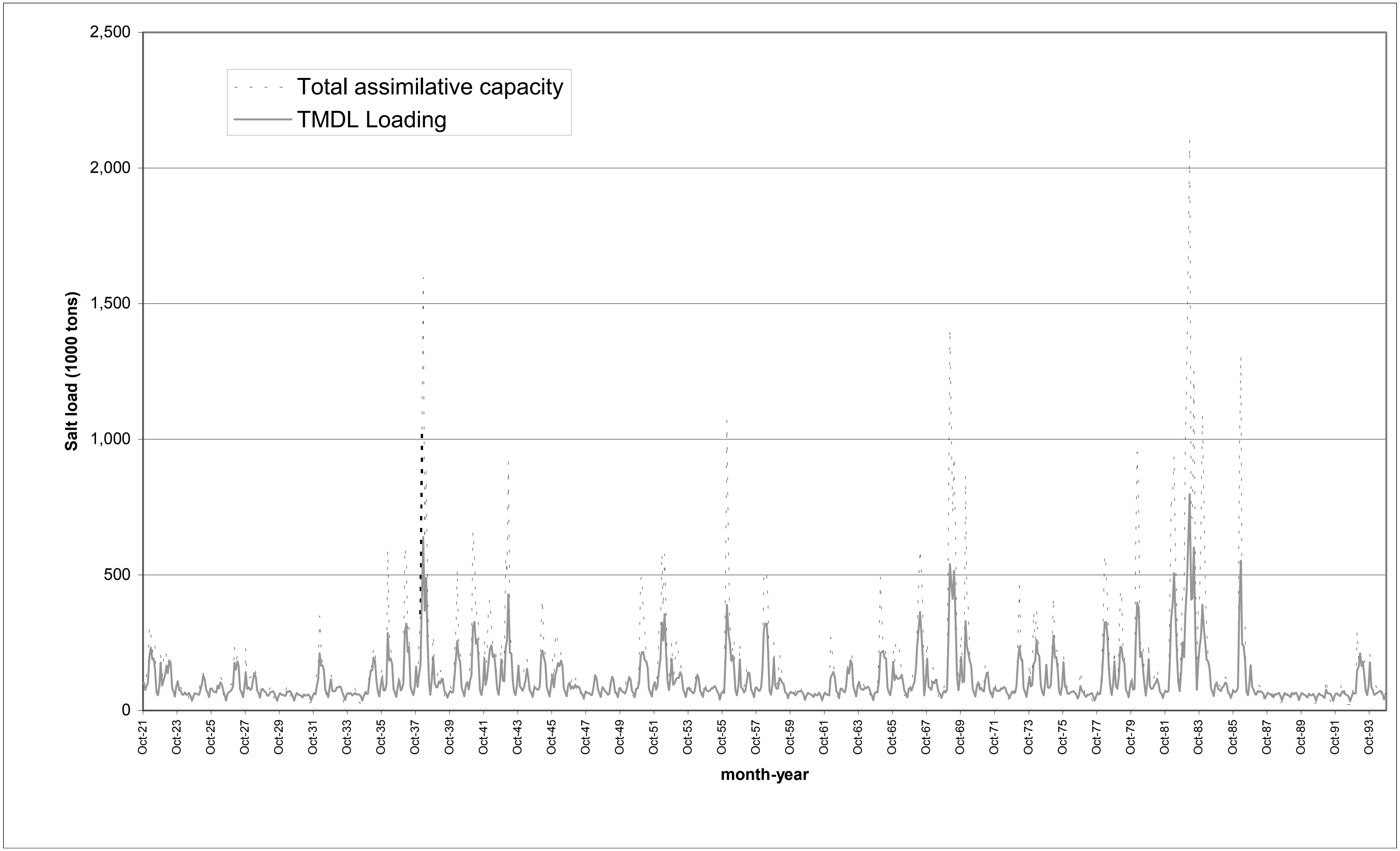
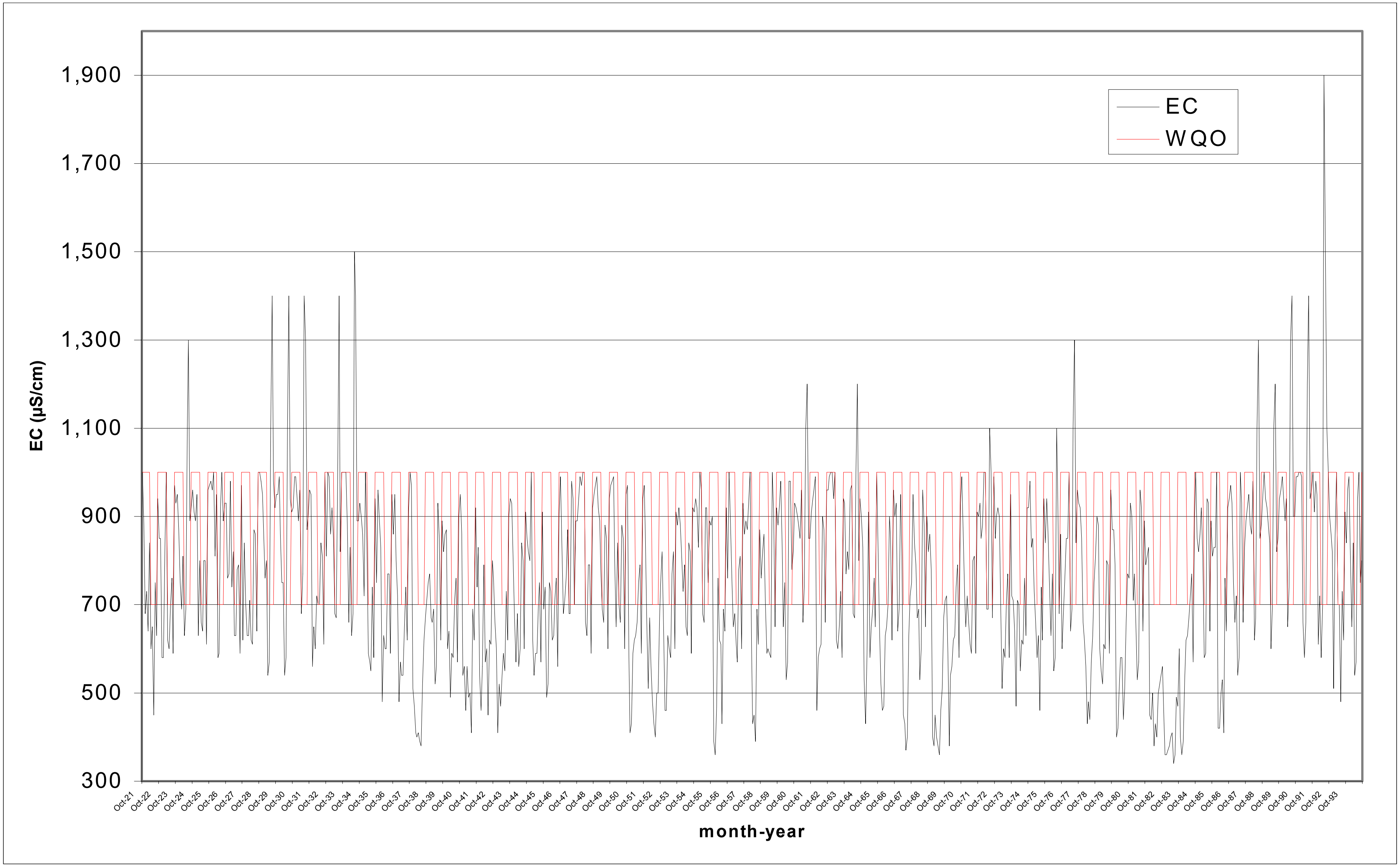
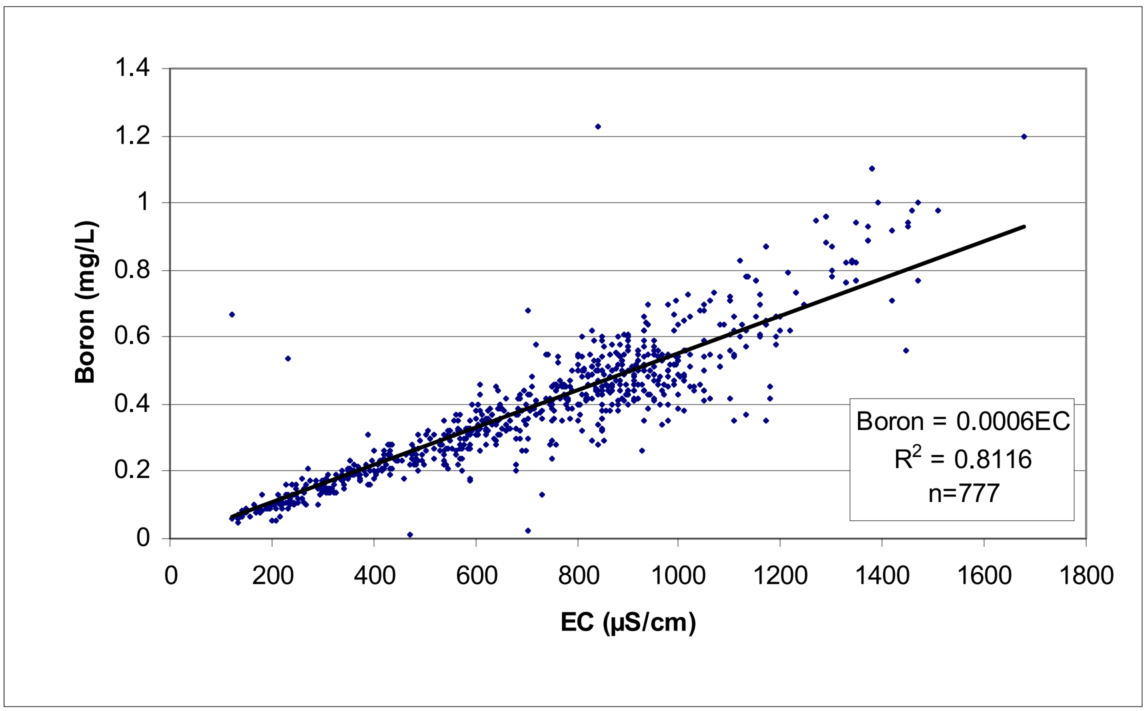


Figure4-4: Comparison of linkage analysis electrical conductivity and the water quality objective from water year 1922 through water year 1994 for the SJR at the Airport Way Bridge Near Vernalis.



Data from the Regional Board's water quality database was used to develop a linear correlation between EC and boron in the LSJR at the Airport Way Bridge near Vernalis (Figure 4-5). The regression equation was used to calculate the expected boron concentration from the predicted EC of the LSJR at the Airport Way Bridge near Vernalis with the TMDL in place. Figure 4-6 compares the expected monthly boron concentration to the seasonal boron water quality objective. The linkage analysis indicates that the boron water quality objective would have been exceeded during 10 months out of the 73-year analysis (876 months) or approximately 1 percent of the time. These 10 water quality violations occurred during months and year-types when no waste load allocations or load allocations were provided.

Figure 4-5: EC VS. Boron Concentration For The Lower San Joaquin River At The Airport Way Bridge Near Vernalis (May, 1985 – June, 2001)



4.7 Boron Waste Load Allocations and Load Allocations

No explicit waste load allocation or load allocations are included in this first phase of the salinity and boron TMDL. The relationship between EC and boron established in the linkage analysis indicates that the salt load allocations will also result in corollary allocations of boron loads. Explicit boron load allocations can be developed for the LSJR at the Airport Way Bridge near Vernalis using the same method used to develop the salt load allocations; however, this would result in overly restrictive salt load allocations because the salt/boron relationship indicates that compliance with salinity objectives is more limiting (restrictive) than compliance with boron objectives. As discussed in the numeric targets section (section 2), the existing boron water quality objectives were never approved by the U.S. EPA. These objectives will be reviewed as part of the Regional Boards on-going basin plan amendment process addressing salinity impairment in the San Joaquin River. Explicit boron load allocations will be developed in subsequent phases of this TMDL to coincide with the new or revised boron water quality objectives. Furthermore, explicit boron load allocations will be developed if future monitoring data indicates that the salt load allocations are not resulting in corresponding boron load allocations sufficient to meet the boron water quality objective.

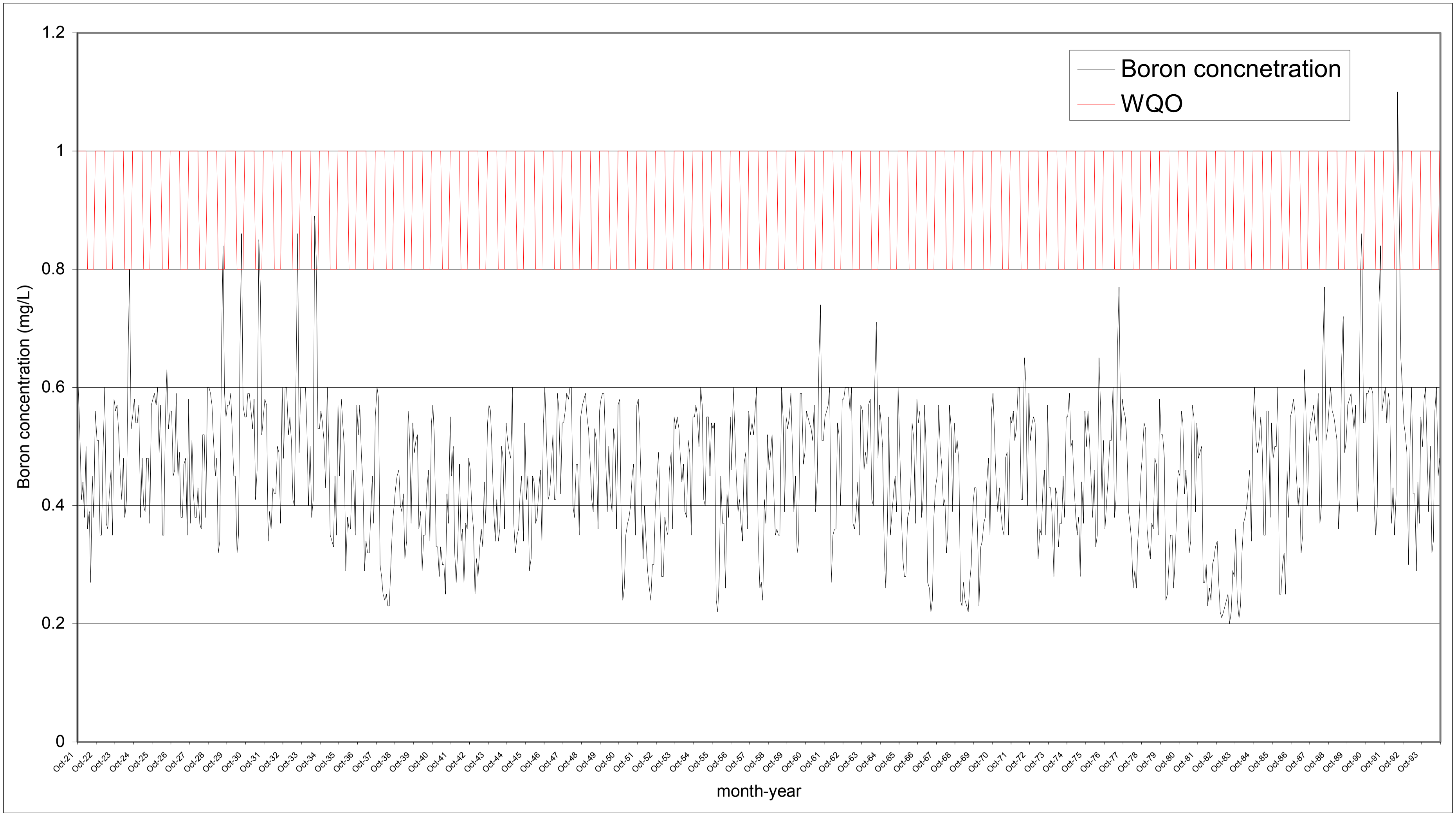
4.8 Summary and Conclusions

This TMDL presents base waste load allocations and load allocations for point and non-point sources. These allocations consider the seasonal variability of flows in the LSJR and include an implicit margin of safety since the allocations are based upon the lowest flow conditions anticipated in the LSJR for each month and water year type. Through an additional consumptive use allowance, the need to provide dischargers the ability to discharge unlimited water that meets a specified water quality has been considered. Further consideration will need to be given to the specific trigger for this allowance, based on further technical assessments and economic analyses that will be part of the TMDL implementation process. Consideration has also been given to the need for providing relief to dischargers that receive a water supply that already contains significant salt loads. A supply water relaxation is allocated to areas that receive salts in supply water to provide this relief. Responsibility for this additional load has been assigned to the USBR to offset this relaxation. The magnitude and the method of both the relaxation and the USBR responsibility may need revision based on further technical assessments and economic analyses that will be part of the TMDL implementation process.

Finally, a real time relaxation is provided to point and non-point source dischargers to allow for achievement of a salt balance in the LSJR Basin while still meeting water quality objectives. Incorporation of the real time component of the TMDL is vital to not only meeting instantaneous water quality objectives, but for providing the framework for achieving long-term compliance with these objectives. The real time re-operation and management framework will need to be identified in the TMDL implementation process.

It is anticipated that some of the model assumptions used in this TMDL will have to be updated to reflect changes in information and models available to estimate impaired flows in the LSJR. For example, the DWR has recently updated the DWRSIM model, upon which the baseline hydrology is based, with the model CALSIM. It is likely that CALSIM will more accurately model LSJR hydrology at the current level of development. The allocations presented in this TMDL are easily updated using such updated hydrology and modeling tools; the baseline hydrology will be updated, as necessary, during the TMDL implementation process.

Figure4-6: Comparison of linkage analysis boron concentration and the water quality objective from water year 1922 through water year 1994 for the SJR at the Airport Way Bridge Near Vernalis.



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APPENDICES A THROUGH G

AVAILABLE SEPARATELY UPON REQUEST